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OF

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CHAPTER I.

INTRODUCTORY.

Value of name.

The name "South Mahratta Country *" is, strictly speaking, a mere geographical term applied to the country which formed the southern part of the Mahratta empire, without reference to the distribution of the Mahratta people.

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* The name of South Mahratta Country is applied to certain districts formerly under Mahratta rule, and includes the Collectorates of Belgaum, Kaládgi and Dharwar, the State of Kolhápur and the Jaghirs of Sángli, Miraj, Kurundwád, Jamkhandi, Mudhol, Rámdurg Akalkot and Sáwant Wari. The spelling of the names of places has been adapted as far as

A very large portion of the South Mahratta Country is inhabited by Canarese people, who differ very widely in appearance, as well as in language, from their Mahratta neighbours. The name in question is, however, practically a very useful one as defining very nearly the limits of the country whose geological structure is to be described in the following pages, and which forms a belt of rather irregular width stretching from longitude E. 77° 40′ near Hyderabad in the Deccan; to the western coast between the town of Ratnágiri and the Goa territory.

Limits and extent of area.

By whom surveyed.

The country here treated of has an area of about 16,000 square miles. Of this, the north-eastern portion was examined by my colleague Mr. King, Deputy Superintendent, Geological Survey of India, and the western portion from the edge of the western ghâts, westward to the sea, by Mr. C. Wilkinson, lately a member of the Geological Survey of India. The central part, extending from the western edge of the ghâts eastward close up to the Madras Railway in the Raichur Doáb, and up to the right bank of the Bhima river from its junction with the Krishna as far north as a line extending from the river westward across Shápur hill to Kembhávi, and measuring about 10,000 square miles, was surveyed by me between December 1869 and May 1874.

Political and fiscal divisions.

This area includes, to the east, a large portion of the Nizam's territory belonging to the Gulbarga and Sholapur taluks north of the Krishna River, and of the Raichur and Ling Sugur (Mudgal) talukas in the Raichur Doáb.* Further west, the central part of the area lies

possible to the system of spelling employed in the official list published by the Government of India. The new spelling is not given in the sketch map accompanying this report, as it had been drawn and lithographed before the publication of the official list. In doubtful cases the names are retained as given in the Atlas sheet. When the new spelling differs much from the old, the latter is given in brackets.

* The triangular area between the Krishna and Tungabhadra rivers, eastward of the frontier of the Bombay presidency.

chiefly within the southern and central talukas of the Kaládgi Collectorate,* but extends southward into the northern part of the Dharwar district. Between the Kaládgi and Belgaum Collectorates lie the small Mahratta States of Jamkhandi, Mudhol† and Ram Durg, and the Kolhapur Jaghir of Torgal. The Belgaum Collectorate, which encloses detached portions of the Sangli and Kurundwád States, together with the southern part of the Kolhapur State, occupies the area westward to the edge of the Ghâts, below which the State of Sawantwari and the southern part of the Ratnágiri Collectorate extend to the sea. A very narrow strip in the south-west corner appertains to the Portuguese colony of Goa.

TOPOGRAPHICAL FEATURES.

Hydrology.

The hydrological system of the South Mahratta Country is very simple, as almost every part of the country above the Ghâts is drained into the Krishna or its tributaries. The actual line of watershed lies, as a rule, close to the edge of the Ghât-scarp and but very rarely bends as much as a mile to the eastward; there are only a few cases above the Ghâts in which the drainage is carried by streams flowing westward, and these are of trifling magnitude. The chief of these are the Mahadayi (Maadwee) river, an affluent of the Goa River, the Tilár, a small river a little to the north of the former. The other cases are of small importance, as the drainage area of each stream rising above the scarp is limited to four or five square miles at the outside.‡

The western off-flow is conveyed into the sea by a number of small rivers, the principal of which, besides the two already named, are in a south to north sequence, the Tirekhol or Pirnim River, the Wurad or

* The Kaládgi Collectorate was formed in 1864 by uniting the eastern taluks of the old Belgaum district with the northern taluks of the old Sholapur district.

† Spelt Moodhul in Atlas sheet 41; a spelling which is, phonetically, quite incorrect.

‡ The other streams rising above the Ghât scarp are the Kunkumbe (Khoonkoombeh) and Chorleh Nullahs, the Talkat Ghât stream, that rising north of Rangna fort, and two or three others of still less importance still further north.

Kodal and Assiamat (Usyamut) Rivers, which fall into the sea respectively south and north of Málwan. Further north, the Seo or Deogarh River, the Viziadrug River, the Sukundi, the Mukhunvi and Kalindi Rivers drain the Southern Konkan as far north as Ratnágiri. The principal affluents of the Krishna, which occur wholly or partly within the limits of the country under consideration, are the Dudh and Ved (Yed) Gangas, the Ghâtprabha, the Malprabha and the Tungábhadra on the right bank, and the Don and Bhima Rivers on the left.

Orography.

The orographical structure of the South Mahratta Country is, geographically considered, quite as simple as the river system, as all the principal lines of hills may be fairly regarded as spurs ramifying eastward or westward from the western ghâts or Sahyadri mountains. The characters of the two slopes are quite diverse. The western slope into the Konkan is very sudden, abrupt and rugged, the eastern one very gradual and slow, and, excepting in a few places, not rugged. The eastern slope of the Ghâts is frequently compared to a series of terraces following one another in downward succession to the sea. This comparison does not apply well to the form of the ground over the greater part of the South Mahratta Country, which is that of an irregular inclined plane, crested here and there by long ridges forming watersheds between the valleys of the numerous rivers, the ridges themselves showing by no means an invariably steady decrease eastwards. The terrace character does, however, appear in the north-eastern part of the area under description in the higher grounds, which commence north of the Krishna in longitude 76° East, and extend in a north-easterly direction up to and beyond the Bhima River near Gulburga, and finally join the Bidar table-land.

Sahyadri mountains, or western ghâts.

The scarped basset edge of the Kaládgi basin and a few outlying table-topped hills to the east of it are not suitably described by the appellation of terraces: on a small scale, the terraced structure is well developed in many parts of the Deccan trap area lying within the limits

of this report; but nowhere was any special relation observed between such terraces and the occurrence of cotton soil spreads. The latter cover rocks of all ages promiscuously.

Eastern spurs.

Two principal spurs run nearly parallel from the crest of the Ghâts for a great distance eastward through our area. Of these, the northern one begins on the edge of the Ghâts just above the famous Hill fort Manohargarh, runs north-east for more than 30 miles, then trends east and north-east-by-east till it reaches Chikóri, after which it runs due east for about 50 miles; and then runs east-south-east till it is cut by the valley of the Ghatprabha close to the junction of the latter river with the Krishna. It re-appears again as a low ridge east of the Ghatprabha, and continues eastward along the south bank of the Krishna till it joins the Sitadongar, the northern end of a transverse ridge, which joins the two great spurs. For want of a better name, this line of heights may, for brevity, be called the North Ghatprabha Spur.

The second great spur which may be considered, called the North Malprabha Spur, starts from the north side of the Talkat Ghât. It soon rises into the high ridge called the Kásar Sadda, then sinks greatly to the north of Chandgarh, but rises again in the high ridge of the Gandharva-garh; it is then cut by the narrow valley of the Tambráparni (Tamburphurnee) River at Rájguli, beyond which the spur runs east for nearly forty miles, broken, however, by the deep narrow valleys of several large nullahs (the Islampur, Markandeya, Belgaum, Kelvi, Iranhatti (Eerunhuttee) and Nandi nullahs). Further east the spur is not broken through, and forms the watershed between the Ghatprabha and Malprabha Rivers for fully fifty miles. It joins the transverse ridge above referred to after having crossed the valley of the Ghatprabha near Kamatgi, and terminates at the junction in the Amingarh hill in longitude 76° East at a distance of 130 miles from the Ghâts, which may, for convenience, be called the North Malprabha Spur. A branch spur is given off from the main one in longtitude 75° 25′ East. The branch trends east-south-east, and then

east till it is cut by the valley of the Ghatprabha a little to the south-east of Bádámi. East of the river the spur re-appears and stretches away east-south-east in a line of discontinous hills, which terminate abruptly a few miles east of Gajendragarh, on the western boundary of the Nizam's territory.

Minor spurs of the Ghâts.

Besides these two principal spurs are a considerable number of others, which start from the watershed of the Ghâts, but which have a much shorter course to run, though in point of height they are often quite equal in importance. The principal of these are the ridge dividing the valleys of the Bogávati and Dudh Ganga and the Dudh and Ved Ganga Rivers in the Kolhapur State, and the great ridge stretching from the south side of the Amboli Ghât north-eastward to the well-known Hill-fort of Sámángarh, and dividing the upper valley of the Ghatprabha from that of its principal affluent, the Harankáshi (Hurruncassi) River.

Two other important spurs among the minor ones are the Mahipálgarh ridge, north-west of Belgaum, and the Bailur (Byloor) ridge to the south-west of that place. Both these ridges are very broken in parts. Lastly, there is the Jamboti Spur, south of the headwaters of the Malprabha, which is interesting as being the most southerly mountain mass within the Deccan trap area.

Western spurs.

The spurs which jut out from the Sahyadri mountains into the Konkan are very much shorter than those running eastward, and, with few exceptions, rapidly fall off in height and are lost in the plexus of little hills lying between the Ghâts and the sea. The highest spurs occur in the north of the Goa territory and the southern part of Sawant Wari State. They all consist of metamorphic rocks, and some are nearly equal in elevation to the general edge of the Ghâts, *e. g.*, a very bold mountain to the south-west of the Chorleh Ghât, said to be the Sálili (Saleelee) hill of Atlas sheet 41. A great height is also attained (retained

would be a more correct term geologically speaking) by the Pargarh Bhekurlé and Hanmantgarh (Humuntgurh) spurs. The longest of these Bhekurlé spurs sinks rapidly after a three or four miles' course. The most remarkable for length and height combined is the Sundur Wari Spur, which consists of gneissic rocks capped at intervals with outliers of the Deccan trap. This spur starts from the Ghâts about six miles north of Amboli, and sweeps round with a gentle northward curve south-westerly past the town of Sundur Wari and then dies down into the general network of low hills. Close to its beginning it is crowned by the two celebrated Hill-forts, Manohargarh and Mansantoshgarh, see plate VII. The more northerly high spurs, which are all trap-crowned, all fall off suddenly very little distance from the edge of the Ghâts.

Outlying ridge and hills.

To the south and south-east of Belgaum is a high ridge of trap once evidently continuous with the Bailur ridge. At its extreme west end it rises into a high and very conspicuous hill crowned by the ruins of a fine old Hill-fort, the Yellurgarh, one of the stations of the Trigonometrical Survey, 3,365 feet above sea level, and 797 feet above the sill of the chief gate of the Belgaum fort. This Yellurgarh ridge runs fourteen miles north-east-by-east, when it touches the southward extension of the great north Malprabha Spur. The ridge runs on three or four miles further in the same direction, and then dies down into the rather elevated plain, which there forms the watershed between the Ghatprabha and Malprabha Rivers.

Between the two great spurs lie a number of smaller ridges and isolated hills which, though of small topographical importance, are important features when geologically regarded. The principal of these are the Shimageri (Sheemagerree) hills south-west of Kaládgi, and the Lokapur hills in the small State of Mudhol, south-west-by-west of Kaládgi.

Kundurgi Hills.

To the north of Kaládgi are two very rocky ridges known as the Kundurgi Hills, which run parallel several miles west-by-north from the Kundurgi village. The northern ridge dies away in the great plain north of Mudhol town; but the southern one joins a low ridge near Wajarmatti, which turns southward to the bank of the Ghatprabha, and is continued across the river in a rocky reef, and rises again into the hills north and west of Jembigi (Jembeegee), which finally disappear in the plain north of Yádwád.

Sita Dongar chain.

The transverse ridge in Kaládgi district which joins the two principal spurs has already been referred to. It forms a great and acute angle to the westward, and this bend is twice cut near its apex by the Ghatprabha River. This ridge is called the "Sitadonga" in Captain Newbold's geological notes of the South Mahratta Country.

Bádámi Hills.

Another transverse band of hills, the Bádámi Hills, joins the north Ghatprabha Spur with the north Malprabha Spur.

Gudur. Hanam Sagar plateau hills.

To the east of the Bádámi Hills, on the right bank of the Malprabha River, is a striking group of detached, flat-topped hills, rising from 300 to 500 feet above the surrounding country. They are capped with sandstones resting on granitoid gneiss, and extend 20 miles east-south-east parallel with the Gajendragarh ridge above mentioned, and, like it, terminate in a bold, bluff headland overhanging the small town of Hanam Sagar in the Nizam's territory. These hills are the easternmost extension of rocks belonging to the Kaládgi series.

The whole of that part of the Raichur Doab (the space between the Krishna and Tungabhadra Rivers) that comes within the area of the map accompanying this report, is occupied by gneissic rocks. Many small groups of hills and many isolated hills are scattered over this large area;

but few are of any importance topographically, except the two groups of granitic hills lying north and north-east of Ling Sugur on the south bank of the Krishna, the one between Jal Drug and Jalihal, the other lying immediately east of Jalihal, and Gallag (Gullug). Another irregular group of schistose hills which lies south of these two groups may be conveniently called the Kautála Hills from the large village of that name* which stands about the middle of their course. At the extreme eastern end of the area are the granitoid hills of Raichur. The last orographical feature in the Raichur Doáb is a narrow ridge running north-westward from near Tawurugiri to Kandagal in Kaládgi district. Beyond this the beds of hæmatite schist, which form this remarkable ridge, have been traced for nearly ten miles, and there can be little doubt that they reappear in the Hunugunda Hill and also further west in the low hæmatitic ridges which may be followed in a north-westerly direction till they disappear under the quartzites of the Kaládgi series at Yerkal, at the picturesque gorge of the Ghatprabha River.

Jaldrug, Jalihal Hills.

Kautála Hills.

Hunugunda hæmatite ridge.

No connection can be traced between these various hill groups of the Doab and the Ghât range, except as far as extensions of the various watersheds may be concerned, for there can be no doubt that many of them had existed as hills at ages long prior to the out-pouring of the Deccan trap flows to which the ghâts owe their present importance in the region under consideration.

On the left or northern bank of the Krishna, nothing worthy of the name of hills occurs till the neighbourhood of Cheemulga is reached. There, and a few miles to the east at Nirgundi (Neergoondee), are some low quartzite and conglomerate hills.

A little further east the terrace character spoken of above (page 4) first appears, and continues along, or very near to, the boundary of the

* Civital of Atlas sheet, 58 north-west ¼.

Deccan trap formation to the north-east and beyond the limits of the sketch-map annexed to this report. This terrace character is especially well developed to the south-east and east of Tálikot, and even more strikingly so yet further east, in the neighbourhood of Gulbarga and Bidar.

A group of granitoid hills, remarkable for their wild and rugged character, occurs along the left or north bank of the Krishna from a little east of Nalutwar, nearly to as far east-north-east as Sorapur. In passing through these hills the Krishna forms a series of great rapids, amounting almost, in one place, to a cataract. This is a little above the very picturesque Hill-fort of Jaldrug. The scene presented by this splendid rapid in the heavy floods during the south-west monsoon must make it one of the most remarkable physical phenomena to be seen in the peninsula of India, but one seen, unfortunately, by very few who are capable of appreciating the beauties of nature. I was not able to see the rapid well on the only occasion on which I visited the Jal Drug gorge (in January 1870), as a small freshet was running down and prevented my crossing the southern branch of the river to a spot whence a good view might have been obtained. I need not, therefore, apologize for quoting in a note the description of the falls of the Krishna* given by Colonel

Chaya Bhoga on the falls of the Krishna.

* Jal Drug and its environs are very fully and graphically described by Colonel Meadows Taylor, C. S. I., in his new tale " A Noble Queen," from which the following description is taken: "And almost as he spoke the spray driven by the wind passed to the other side of the chasm, slowly unveiling by degrees the noble cataract which he could now see nearly from the top, whence the water of the mighty river precipitated itself to the bottom where it was partially veiled with spray. The river was full from bank to bank, and about a quarter of a mile, perhaps indeed, more in breadth, and fell from point to point, or step to step of the incline of 400 feet with a fearful crash and clamour. In no part of its course, except one, was the rock perpendicular, but it was broken by huge masses of rock which showed their tops only in a few places. The steps of the whole incline were in irregular portions which caused breaks in the fall and added to its sublimity. Here and there the action of the water had hollowed out large, deep holes which now and again spouted forth columns of water and spray to a surprizing height, and fell back with a roar and splash with marvellous effect. The whole was a seething, roaring mass.

Meadows Taylor, whose long residence both at Sorapur and Ling Sugur gave him ample opportunities for visiting that very picturesque region frequently and at the proper seasons. This group of hills is continuous geologically with that of the right bank of the Krishna mentioned before at page 9.

Sorapur and Shahpur.

The Sorapur* Hills, and sundry scattered granitic hills in the Sorapur Taluk, amongst which are the Shahpur (Shawpoor) Hills, indicate a former connection with the granitic hills east of the Bhima, which form a chain of heights extending eastward beyond the limits of the area to be described in these pages.

"Again, the Beydur Chief spoke: 'The pool is clear Meeah' he said, 'see, it is like all the horses in the world tossing their manes and fighting.' It was indeed a frightful place to look upon. At his feet, as it seemed, in a wide pool at the foot of the fall, the tremendous masses of water falling into it met other currents and eddies of equal power, and dashing together raised enormous waves which met in innumerable shocks and cast their spray high into the air, whirling, foaming, breaking with inconceivable violence and grandeur, almost impossible to look on with a steady eye for a moment together. Yet the Beydur, to whom the scene was familiar, beheld it with a serene gravity. "This is the nymph in her fury," he said, 'and we worship her and cast flowers and our simple offerings into her bosom to appease her. When it is past we can wander over the rocks and make offerings at the holy pools which now vomit forth the columns of water you see rising, and the pool now so fearful to look upon is as still as a lake.'

"The banks of the chasm were huge piles of granite rock covered with trees and brushwood which seemed to bend in homage to the genius of the place; and they were all now lighted up with roseate tints, while the deep shadows of the ravine increased the beauty and solemnity of the scene.

"In dry weather the stream was reduced to a comparatively small compass, the cataract was divided into many portions threading through the rocks in their white streams and disclosing the whole of the wonderful formation of the fall, huge masses of granite rock, crossed by veins and dykes of basalt. From the crest of the cataract to the pool beneath, the measure by level of the descent is 408 feet in about a quarter of a mile, and, as I have before attempted to describe the fury of the decending mass of water, when the river is in flood, is majestic and wonderful in the extreme, but the place is so lonely, so entirely out of the way of ordinary travellers, that, except the people of the country immediately round, few know of its existence."

* For a full description of these hills, see Captain Meadows Taylor's Sketch of the Geology of the District of Shorapoor or Soorpoor in the Dekhan.—Journal of the Geol. Socy. of Dublin, Vol. X, pt. 1, 1862-63.

This review of the principal geographical features of the country under discussion suggests two questions—firstly, whether it is possible in any of those features to recognize the peculiar character of the denuding agencies which brought about the present state of things; and secondly, whether any inferences can be drawn from the form and structure of the older land surfaces as to the agencies by which they had been shaped. The first question is easily replied to. There are distinct evidences of the action of the two great forces of denudation, namely sub-aerial and marine denudation, having both contributed to the formation of the most important and greatest of the existing mountain features, the Sahyadri Mountain Range (or Western Ghâts) with its great westerly scarp.

The strong contrast in appearance between the grand Western Scarp of the Ghâts, with the low country of the Konkan at its base on the one side, and the eastern slope of the Ghât region on the other, must strike forcibly any observer who stands on some summit commanding views of both tracts of country. Their dissimilarity suggests at once the reasons for such great difference in shape and character of scenery. The Ghât region, with its long stretching valleys, V-shaped in section, running between terraced hills, at once reveals its having been formed by sub-aerial denudation alone. The great cliff-like scarp and gently sloping low country at its base, suggest, on the contrary, the action of marine denudation on a great scale—operating during a period of gradual elevation, the result being subsequently much modified by the tremendous sub-aerial influences of the south-west monsoon, which must have begun as soon as the scarp had been elevated sufficiently to form an obstacle to the great cloud-drifts.

The plain of marine denudation, formed after the out-pouring of the Deccan trap-flows had ceased, is well shewn in a sketch section given by Mr. C. Wilkinson, who examined the Konkan (Plate VIII, Section 6). The whole of the Deccan trap denudation above the Ghâts and across the Deccan, presents features of purely sub-aerial action;

and there is no reason to suppose that any part of it, except what forms the floor of the Konkan, has been at any time depressed below the sea-level. The surface is everywhere uneven, and no approach to a marine plain of denudation was seen. A certain apparent levelness in parts of the country is due really to the nearly horizontal position of the trap-flows, and to their general homogeneity of texture over large areas.

The rate of denudation of the trap rocks is a very high one, and apparently greater in the dry, hot climate of the Deccan, than in the moist and cool climate in the mountain region.

The second question—whether any inferences can be drawn as to the character of the agencies which shaped the older land surfaces—admits of much less satisfactory answer, because of the comparatively very small amount of evidence remaining. Of the surface on which the Deccan trap-flows were poured out, there is every reason to conclude that it was a true land-surface, occupied probably here and there by small lakes, the traces of which remain in certain small sub-trappean deposits of gravel, sandstones, marls and clays of limited extent, which will be found described further on. The shape of that land-surface as it then stood was unquestionably of sub-aerial formation; but whether the rather level character of the general surface of the series of azoic sedimentary rocks on which the trap flows chiefly rest may not have been a remaining feature of a previous marine plain, is an open question. In the Konkan region, Mr. Wilkinson's very interesting section, above referred to, seems to show that there the Deccan trap had certainly been poured out over a true plain of marine denudation.

The character of the surface of the gneissic rocks on which the last-named azoic rocks were deposited was eminently that of a marine plain of denudation. It was of very wide extent and showed but very few inequalities, and those only of the very hardest and most unyielding rocks.

Three zones of elevation and climate.

The climatic conditions of the three zones into which the South Mahratta Country is divisible are very distinct, and in the case of the two first, the boundary between them is very clearly defined. The three zones are the country below the Ghâts, or Southern Konkan, the Ghât region, and the Deccan region. The differences of climate are marked, and depend upon the rainfall during the south-west monsoon and the relative elevation of the land, and may be defined as follows:—

The Konkân	... ...	Wet and hot.
The Ghât region	... ...	Wet and cool.
The Deccan region	... ...	Dry and hot.

The eastern limit of the Ghât region is not naturally well defined; indeed, in some parts it may be considered as shading off into the Deccan region. In other parts, however, there is a decided change in the vegetation and in the nature of the shelter the natives provide for themselves, the flat mud roofs of the Deccan being suddenly replaced in certain villages by tiled pent roofs. As far as my own observations go, I incline to draw the eastern limit of the Ghât region from north to south through Nipani (Neepanee) and Sankeshwar; thence it runs eastward to Pachhápur, and then trends south past Ankalgi (Unkulgee) and Marrihal to the Yellurgarh trap ridge. To the south of this it trends southward to the crossing of the Belgaum and Dharwar road over the Malprabha. The diminution of the rainfall from the crest of the Ghâts eastward is steady and well-marked; but to the eastward of the boundary line just traced, the diminution in the amount of atmospheric deposition is very sudden, and is accompanied by a decided change in the aspect of the local flora, a change which is patent to the eye even of the botanical layman. The change of the climate is also made very apparent by the sudden change in the architecture of the native houses;—on the western side of the boundary line they have all tiled pent-roofs with wide eaves to carry the water well clear of the mud walls; on the eastern side the great majority of houses have flat

terraced roofs, constructed of beaten mud, and calculated, therefore, to resist rains of only very short duration.

The seasons. The two monsoons.

The seasons depend on the two great monsoons, but of these the south-west monsoon is incomparably the more important and the more constant in its phenomena. Its influence reaches over the whole of the South Mahratta Country and far beyond it, into the heart of the Deccan. The effects of the north-east monsoon, as a rule, are not greatly felt westward of Kaládgi, and the rainfall accompanying it is much less in quantity and duration.

The cold weather lasts from November to the end of February, and during that time fine weather prevails, with strong, dry, easterly winds. Occasional showers occur, however. In March the hot season begins and the temperature rises rapidly. The prevalent wind is a westerly one. In April and May the great heat gives rise to local thunderstorms which are sometimes accompanied by very heavy rain.* Sufficient rain, however, falls all over the country to make it assume a very much less burnt-up appearance than it had in March. As the south-west monsoon approaches, the storms become more frequent and heavy—so much so, that in some seasons, as in 1874, it is hard to tell which storm is the first burst of the true monsoon. In the Belgaum and Dharwar districts, the advent of the monsoon is generally looked for on or about the 5th of June. The monsoon rains effectually cool the air even further east than Gulbarga and Raichur, and the ploughing of the land for the great crop of jowari is now taken in hand. On the Ghâts and near to them, the rainfall is very constant and heavy and continues till well into September; but further eastward it is fitful, and falls only in showers with intervals of dry weather between.

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* A thunderstorm I experienced at Wattar on the Kolhapur territory in April 1874, was accompanied by a short, but very severe, hailstorm. The hailstones were decidedly large (¼"—½" in diameter and upwards) and lay unmelted on the ground for some minutes.

By the middle of October the north-east monsoon is looked for, but in many seasons it does not burst over the country till the end of the month, or even till the middle of November. As a rule, it is much milder in the Raichur Doab than further south, and occasionally it fails almost entirely, and thereby causes a water-famine in the higher parts of the Doáb. The rainfall of the north-east monsoon is not much reckoned upon further west than the Doab, though in good seasons the Kaládgi districts and the eastern parts of Dharwar district often receive a very welcome supplement to their south-west monsoon water-supply. In exceptional seasons such as 1874, the rains extend to the Western Ghâts, and the Krishna and Tungabhadra come down in heavy freshets.

North-east monsoon.

The climate of the South Mahratta Country and the South-Western Deccan is decidedly cooler than that of the South-Eastern Deccan, as might be expected from its greater elevation. The great difference of temperature between the cold nights and hot days renders it, however, quite as trying a climate to those exposed to its vicissitudes. The westerly wind which prevails during the hot weather does not acquire the character of a fierce hot wind till it reaches the bare plains lying eastward of Bijápur and in the western parts of the Doáb. It is in passing over those treeless tracts that it acquires the fierce heat with which it blows in the districts traversed by the lower Krishna valley, and which can be most aptly compared to the blast from a furnace-mouth.

On the Ghâts the climate is a damp one, even during the hot weather. Soon after noon, a thick, misty haze begins to form in the valleys, and, rising gradually, renders distant objects very indistinct and hides all the details of the landscape. It is not, however, without a beauty of its own. This haze is often so thick over the Konkán, that the disc of the setting sun is greatly distorted. Even in the early morning the atmosphere is hardly ever so clear as it generally is on the mountains further south in the peninsula.

The Ghât climate essentially damp.

Malarious and non-malarious seasons.

One singular, and, I believe, as yet unexplained, difference in climate exists between the Ghâts in this quarter and the more southerly mountains, such as the Nilgiris, Anamalais, Palnis, Shervaroys and others in the Carnatic. In the latter forest-clad mountain regions the unhealthy season is during the dry hot weather, extending from the end of February* till the setting in of the south-west monsoon rains in June, the most healthy season being in the cold weather. In the Belgaum and Kolhápur Ghâts, on the contrary, the cold weather is esteemed very feverish, while the malarious influences have ceased to act, or very nearly so, by the beginning of March, and are in abeyance in April and May. Whether they are perfectly free from malaria at any other season I am unable to say.

Schedule of geological formations in the South Mahratta Country.

The complete series of geological formations met with in the South Mahratta Country and South-Western Deccan may be conveniently tabulated as below in descending order; but in the descriptive chapters the several formations will, with advantage, be considered in ascending order:—

Post-Tertiary or Recent ...	11. Sub-aerial formations and soils.	
	10. Alluvial deposits.	
Later Tertiary?	9. Ossiferous gravels, &c., of river valleys.	
	8. Konkán laterite.	
Lower Tertiary ...	7. Ratnágiri clays with plant remains and lignite.	
Upper Secondary	6. Deccan trap and Iron-clay (laterite) formation.	
	5. Inter-trappean formations.	
	4. Infra-trappean formations. Lameta group?	
Azoic	3. Bhima (Karnúl) series ...	Upper.
		Lower.
	2. Kaládgi (Kadapáh) series	Upper.
		Lower.
	1. Gneissic (metamorphic) series	

* The Malai-ála or Hill-men of the Salem mountains, generally believe the malaria season to begin with the fall of the bamboo leaf in February.

Description of the several rock areas.

Of these several rock series, the gneissic is the most widely developed, and occurs chiefly in the eastern, southern, and south-western parts of our area. The Deccan trap covers very nearly as large an extent of ground in the western and northern parts. The Kaládgi series of azoic rocks is chiefly met with in the central and western parts of the area, and lies between the areas covered by the gneiss and Deccan trap series, covering a much smaller surface than either of those. The Bhima group of rocks occupies a yet smaller area in the north-eastern part of the country under consideration; and, like the Kaládgi series, shows as a band between the underlying gneiss and the overlying Deccan trap.

The Konkán laterite covers a much smaller surface than any of the foregoing series, and is confined to the extreme western part of our area. The remaining series are of very limited extent, and make a very small show on the map.

CHAPTER II.

SYNOPSIS OF PREVIOUS OBSERVATIONS.

Lieutenant Rigby.

The earliest writer on the geology of the South Mahratta Country appears to have been Lieutenant C. P. Rigby, 16th Regiment, Bombay Native Infantry, whose account of a collection of geological specimens for presentation to the Bombay Asiatic Society was published in volume VII of the Bombay Geographical Society's Transactions. In this paper, Mr. Rigby described the town of Talikote as standing on an extensive bed of very fine clay (limestone really) used for building and roofing purposes, and occurring of many colours. He noticed the occurrence of some limestones fit for lithographic purposes; also the saltness and bitterness of the water of the Dón River. He describes the country south of the Krishna, towards Belgaum, as almost wholly composed of red sandstone and red ferruginous claystone (?) with intervening plains of rich black soil. The fact of the Jain temples, which stand above the falls of the Ghatprábha at Gokák, being built of the local sandstone, is also mentioned.

Dr. Voysey. 1819.

Dr. Voysey's observations on the "iron-clay" of Bidar have a direct bearing on the geology of our area, for the iron-clay plateaux, occurring to the north-east of Galbarga, are extensions of those capping the Deccan trap in the Ghát region. He was the first to point out the formation of iron-clay by decomposition of basalt and other volcanic rocks rich in iron. He used the term iron-clay exclusively. In his description of the country at and around Bidar, he noticed the striking flatness of the isolated mountains; the resemblance of the iron-clay to the Nellore rock, which is a true sedimentary laterite. He dwelt specially on the passage of the iron-clay into "wacké and thence into basalt," and instanced a case in which the very distinct transition took place within a distance of 3 feet.

Colonel Sykes. 1833.

The well-known paper on the geology of a portion of Dukhun, East Indies, read before the Geological Society of London by Lieutenant-Colonel Sykes, F. R. S., H. I. O. S., touched very slightly upon the South Mahratta Country, merely referring to the extension of the Deccan trap to the Krishna, south of Bijapur. In speaking of the extent of the trap area, he assumed that a basaltic dyke in the neighbourhood of Seringapatam (described by Dr. Voysey) must belong to the Deccan trap, thus assigning a vastly greater extension to the great trap area than is warranted by the evidence. He drew no distinction between the low-level Konkán laterite and the iron-clay capping the trap flows on the summits of the Western Ghâts, some 3 or 4,000 feet above the former. He assumed also, with Dr. Voysey, that the basis of the whole peninsula of India and Ceylon consisted of granite, and was therefore of igneous origin. The metamorphic origin of many granitoid rocks had not then been recognized.

Dr. Christie. 1836.

The first general sketch of the geological structure of the South Mahratta Country was given by Alexander Turnbull Christie, M. D., and published in the Madras Journal of Literature and Science. Though many of his conclusions cannot be accepted now, it is impossible not to admire his work as that of a painstaking and accurate observer; but he was unfortunately trammelled by a strong desire to bring the rocks of the peninsula into absolute correlation with the classification then in vogue in Europe.

He was not fully aware of the occurrence of large and important bands of schistose rocks in the Raichur Doáb; and, in common with his predecessors and contemporaries, regarded the great bands of granitoid gneiss, so largely developed in and beyond the Doáb, as true granites. His description of the scenery in such granitoid districts is very good and true. He had observed the predominance of the hornblendic variety of granitoid rocks, and mentions the very handsome porphyritic form occurring at Gajendragarh (Gudjunturgarh). The great quartz-runs

and trapdykes occurring in the granitic rocks, or as they are now classified, the gneissic or metamorphic rocks, had also attracted his attention.

In his grouping the rocks of the South Mahratta Country he was not very happy, for he associated in one group various members of the gneissic series, such as the chlorite, hæmatite, and talc schists, together with the uncomformably overlying quartzites in part, limestones and argillaceous beds of the Kaládgi series, and classed it with the transition rocks of European geologists.

The quartzites and their associates he classed as old red sandstone, remarking that "some geologists might be disposed to arrange this sandstone with the old red sandstone of English geologists (transition red sandstone of the Germans); but I am inclined to consider it identical with the old or new red sandstones of the Wernerian Geognosy; and, therefore, as very generally disposed in an unconformable position in regard to the transition rocks.

From insufficient examination of the country, he had not recognized the fact that the Kaládgi limestones overlie the great sandstone (quartzite) series.

His description of the Badami hills is good.

He failed to distinguish the old, highly crystalline trapdykes occurring in the gneissic area from the far more recent and much less crystalline Deccan trap.

He described the "iron-clays" or "laterite" of Buchanan resting on both gneiss and the Deccan trap, but offered no opinion as to its origin.

The black cotton soil, or regur, he held to be an alluvial clay, derived from the decomposition of the Deccan and other trap rocks, and that were it "again consolidated, it would form an immense overlying formation of a substance resembling basalt or wacké."

The next reference to the geological structure of the South Mahratta Country is contained in the well-known paper "on the fossils of the eastern portion of the great basaltic district of India" by John G. Malcolmson, F. G. S., read before the Geological Society of London in 1837.

Malcolmson. 1837.

In this paper, Dr. Malcolmson mentioned the extensive distribution in the South Mahratta Country of sandstones and schists of the same characters, and associated with the same rocks, as those occurring in the Kadapáh district, and described his discovery of the sandstone below the escarpment of the Western Gháts at Atchera (Achura of Atlas sheet), north of Malwan.

The sketch map of the South Mahratta Country accompanying his paper approximates but distantly to the reality, for the main boundary of the Deccan trap is made to run well north of both Kaládgi and Belgaum, which latter place is represented as standing on an outlier of the trap, in lieu of at the edge of the main spread.

The outlier of trap (?) or "argillaceous limestone" (?), shown immediately north of Dhawar, has really no existence. The outlier at "Noulgound" (Naulgund) is also wrong, as no argillaceous limestones occur there; only a small ridge of quartzite, which most likely belongs to the gneissic series.

The existence of the limestones and sandstones, &c., forming the Bhima series must have been unknown to Dr. Malcolmson, as the region occupied by them is either left blank, or else colored as granite and gneiss.

The next writer who touched upon the geological features of the South Mahratta Country and adjacent parts of the Deccan, was Captain Newbold, F. R. S., Madras Army, the best informed and most acute and accurate of all

Captain Newbold. 1842-45.

the earlier students of South Indian Geology. Four of his papers refer to parts of the country here treated of; they are—

"Notes, principally geological, across the Peninsula from Masulipatam to Goa, &c."

"Notes, principally geological, on the tract between Bellary and Bijapur.

"Notes, principally geological, from Bijapur to Bellary, *viâ* Kannaghiri."

"Notes, principally geological, on the South Mahratta Country, &c."

In the first of these he gave an admirable description of the Bidar laterite (iron-clay), in which he first discovered small veins of oxide of manganese. His account of the simulation of true stratification by the presence of horizontally disposed cavities, and their having been caused by the lodgment of water that could only escape laterally, is unquestionably correct. He noted the limestone (now reckoned with the Bhima series) which underlies the Deccan trap, south of Gulbarga; also the occurrence of limestone at Chimalga on the left bank of the Krishna.

In the second paper quoted, Captain Newbold referred to the granite (granite-gneiss) hills near Tawurughiri in the Raichur Doáb, known as the "Caradi Guddi" or Bear Hills. He also mentioned the former existence of an iron-smelting industry crushed by the exactions of the Musulman Government. The occurrence of a band of chloritic schist to the north-west of Tawurughiri was also observed. The jaspery clay iron beds near Kamdigul are referred to, and the sequence of the various gneissic rocks met with from there to the ford over the Krishna near Dawurs* is then given. He examined the gravel of the Krishna valley to see the character of the rocks traversed in the

* More generally known now as the Tangurgi (Tungurgee) ford. The new road from Hungund to Bagehvári and Bijápur crosses this ford.

course of the river. On the north side of the Krishna he noted the great quantity of tufaceous matter deposited on the surface of the gneissic rocks, and further up the valley of the Hirri or Bagewari nullah, near Behlal, the peculiar effect produced by the weathering of the basaltic trap into a wacké in which the concentric lamellæ are extremely conspicuous around the hard basaltic nuclei which stand up over surfaces like so many badly-laid paving stones in an old road.

Captain Newbold's third paper commences with a capital sketch of the geological features at and around Bijápur. In one point, however, he was mistaken, namely, in supposing that the flat-topped hills to the north-west horizon showed walls of sandstone; they are purely trappean in composition. He noticed the subaerial conglomerate formed by the union of lateritic gravel and nodular kankar by a calcareous cement, which occurs on the high ground south of Bijapur. His route then ran outside the area here treated of, but he re-entered near Talikot, where he saw the limestones (of the lower Bhima series) and noticed the lithographic character of some of them. The mill-stone quarries at Kuntoji near Muddebihál in the basement sandstone bed of the Bhima series also attracted his attention.

In the Raichur Doáb he noticed the occurrence of granitoid rocks near Kannaghiri south of the schistose tract described in the second paper.

He concluded the third paper with some remarks on the extent of the Deccan trap area, which he estimated at 250,000 square miles. With his characteristic acuteness he had perceived what all his predecessors had failed to do, that the trappean rocks, diorites, basalts, &c., occurring as dykes in the gneissic region, were of much greater geological age than the flows of the Deccan trap period.

His fourth paper is a sketch of the country lying along the right bank of the Gatprabha from its junction (or Sangam) with the Krishna westward as far as the falls of Gokák, and thence south-westward to

Belgaum and on to Dharwar, south of the area of this report. He commenced with an account of the alluvium seen at the junction of the two rivers just named, and argued against the theory of the fluviatile origin of the greater regur spreads, as also against the idea of regur being a mere product of decomposition of trappean rocks. He pointed out the fact that the trap rocks in weathering form a detritus of reddish or coffee-brown color.

The hornstone-breccia south of the Gatprábha attracted his attention; also the highly silicious limestones further to the south-west. He crossed the Sitá Dongar range, which forms the eastern side of the Kaládgi basin, *en route* to Bágalkot somewhere near Yerkal,* and noticed the varying character of the silicious rocks ranging from coarse conglomerates to fine, rippled quartzites. At the western base of the pass he noted a dyke of "basaltic greenstone" cutting through colored argillaceous shales, converted into reddish, greenish, and brown-colored jasper and bluish-white chert. These jasperized schists would appear to belong to the jaspery hæmatite-schist beds which form great cliffs in the gorge of the Gatprábha at Yerkal. He crossed the Bágalkot bend of the Sitá Dongar, and then visited the plains of Bágalkot and Kaládgi, and described the limestones and shales there occurring, together with the overlying laterite deposits, with his usual accuracy. He did not, however, recognise the quartzites and conglomerates south of the Bágalkot-Kaládgi road as being a younger series than those seen in the Sitá Dongar. The slate quarries at Kátarki on the Mudhól road and at Sittikeri south of Kaládgi, the former yielding good hones and the latter fair roofing slates (really hard shales, for the lamination is true bedding, not cleavage), were also visited by Newbold.

From Kaládgi he proceeded westward *viá* Lokapur, between which and Hulkund he noted four dykes of greenstone intruded in the

* I cannot, from his description, identify positively the pass by which he crossed the Sitá Dongar ridge, and did not myself observe the metamorphic action of the dyke referred to immediately afterwards.

limestones; these are interesting, for, with one exception, they are the only trappean intrusions met with in the Kalâdgi basin.

He further pointed out the existence of several sandstone outliers west of Kalâdgi, especially the Manikeri (Munnikerry) ridge, and the overlying trap formation; also the loose sandstones occurring at Uparhatti, which he recognised as newer than the compact quartzites and sandstones below the trap, and held to be probably associated with the laterite. He did not observe that these beds are overlaid by trap and are true inter-trappean beds containing an *Unio (?Deccanensis)*. He then described the geological features of Gokâk, and gives an admirable account of the great fall of the Gatprabha, which will be referred to frequently when treating of the Gokâk section.

He next describes the country between the fall and Belgaum, proceeding *viâ* Padshahpur across nearly horizontal beds of sandstone nearly to Belgaum, when trap is again met with, which is overlaid by laterite in the town and part of the cantonment. After noticing the special mineral peculiarities of the basaltic trap hills around the town, he points out their generally rounded form.* His remarks on the country included in the area here reported on are concluded by his noticing the hæmatitic, silicious schists and hornblendic schist beds lying between the southern boundary of the trap area and the Malprâbha river.

In his remarks on the classification of rocks, he points out that, in the absence of any organic remains, and without a single associated stratum having had its geological horizon determined, Dr. Christie was not warranted in referring the rocks of the South Mahratta Country to the epochs of the transition, grauwacké and old red sandstone of Europe as then defined, and himself adopts a classification of relative

* These rounded forms are, however, only found in the small hills near Belgaum. The larger and more distant masses, especially those capped by the iron-clay (laterite) beds, are characterised by true table tops.

age of the several formations. The hypogene schists (now known as the gneissic series) he shows to be the lowest of the stratified rocks. He differs from Dr. Christie as to the age of the Kaládgi limestones and shales which he shows to be unconformable as a rule to the "hypogene schists." To the sandstone series he assigned no age in the absence of fossil remains or other satisfactory evidence, such as the presence of diamonds, which might be held to correlate it with the diamond sandstones of Central India and the eastern side of the Peninsula.

The "iron clay" and laterites he treats all as one formation, and as of the same age as the coast laterite on the Coromandel and Malabar Coasts (which are true sedimentary deposits, and frequently conglomeratic in character), and argues against the theory of formation of lateritic rocks by decomposition of trap and other ferruginous rocks. He inclines to regard the laterite on the trap as a sedimentary formation analogous to the inter-trappean beds.

Coming to later deposits, he mentions having seen no gravels in the South Mahratta Country.

The age of the plutonic and trappean rocks is then discussed, and he arrives at the conclusion that there were two eras of plutonic disturbance, the first of which caused the metamorphism and uptilting of the hypogene schists prior to the formation of the sandstones and limestones, the second posterior to their deposition and accompanied by another granitic eruption.

He supposes a third period, or series of movements, during the tertiary period, by which the laterite beds capping the trap formation were raised in a horizontal position to the height of 7,000 feet or more, this great upheaval being volcanic rather than plutonic in kind.

The absence of unaltered fragments of undoubted granite or gneiss among the pebbles in the conglomerate of the sandstone series led Newbold to speculate on the subject; and he concluded from it that

either the oldest granite was still undenuded at the time these conglomerates were forming, or else that excessive attrition of the other rocks destroyed everything but their very hardest constituent parts. The latter view is partly correct, but goes too far, for many of the conglomerates are largely made up of pink felspar derived directly from the granitoid rocks.

He recognises the fact that the trap dykes in the South Mahratta Country belong to two ages, the one prior to the deposition of the "sandstone," the second posterior to the sandstones and limestones (Kaládgi series), but anterior to the Deccan Trap period. Nor did the great mineralogical differences between these basaltic greenstones (diorites) and the basalts and amygdaloids of the Deccan Trap series, which he regarded as of tertiary age, escape his observation.

He gives the following tabular statement of the succession of formations in descending order in the South Mahratta Country:—

Regur	1st group.
Old kunker	
Laterite	
Lateritic sandstone	
Overlying trap	
Basaltic greenstone	2nd group.
Granite	
Sandstone	
Basaltic greenstone	3rd group.
Granite	
Hypogene schists	

The first group he regarded as tertiary; the evidence in case of the second he inclined to consider as pointing to its being of carboniferous or Devonian age; and the third as Silurian or Cumbrian, if the Devonian age of the second group be established.

Captain G. Wingate, Bombay Engineers, published an interesting series of "Remarks on the Laterite of the Southern Konkan and Southern Mahratta Country" in

Captain Wingate, 1852.

Vol. X, p. 287, of the Bombay Geographical Society's Transactions, in which he endeavoured to prove that all the laterite in the Southern Konkan as well as that above the Ghâts is a product of decomposition *in situ* of ferruginous rocks. He quotes a beautiful example of the passage of trap into laterite at Viziadroog, and points out that even the obscurely prismatic structure of the original trap bed is still visible in the laterite exposed in the scarps of the fort ditches. Captain Wingate thought that even the hard sandstones (quartzites) of the Phonda ghât and Malwan weathered equally into a laterite but of a different character, gritty and full of undecomposed quartz. He also pointed out the existence on top of the ghâts of laterite derived from the decomposition of both metamorphic schists and traps.

Lieutenant Aytoun, 1852-54.

A geological report on the Bágalkot and part of the adjoining talooks of the Belgaum Collectorate* by Lieutenant Aytoun, of the Bombay Artillery, was the next contribution to the geology of the South Mahratta Country. This is an elaborate paper, but very speculative in parts and by no means lucid in others. He failed to realise the real relations of several formations, partly from attempting too much in a brief space of time and when out of health, and partly from want of sufficient experience as a field geologist. His descriptions of rocks are generally good and trustworthy, but his attempts to explain their relative stratigraphical positions are in various cases singularly unhappy, as will appear from a study of his sections.

He commences by supposing that the altered condition of the sandstones, schists, and limestones met with in the district in question, is due to the presence of plutonic rocks underlying the sedimentary formation from one end to the other, but nowhere visible on the surface. Inequalities in the old surface on which the sandstones rest were looked upon as intrusions.

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* Published in the Transactions of the Bombay Geographical Society, Vol. XI, p. 20, 1854.

The most serious error he fell into was the assumption that the Deccan Trap underlaid the sandstones, as shewn in Figs. 1 and 9 of his plate of sections and elsewhere in his descriptions; and he credits the trap with having caused many of the changes in the overlying rocks.

His first and third and part of the second sandstone ranges, as shewn in his three first sections, are really parts of the continuous chain of hills formed by the lower Kaládgi quartzites. The second range in his section 1 is really formed by the upper quartzites; in section 2 he represents the beds as dipping south instead of north, and reposing unconformably on the gneissic rocks. In section 1 he represented the second sandstone range 'f' as having a distinct southerly dip, whereas really the beds are vertical or dip north at a very high angle, and form a synclinal fold with 'd' (the Arrakeri ridge), called a sandstone undulation. In section 9 the southerly dip of 'e' (equivalent of 'f') is really southerly, because of an inversion of the beds. The outcrop of the upper Kaládgi quartzites south of Bágalkot, and forming the northern side of the Shimakeri synclinal ellipse, he calls the fourth sandstone range.

After describing the conglomerates and breccia beds north of Bágalkot, and the limestones between that place and the "fourth sandstone range," he proceeds to give a full account of a remarkable occurrence of calcspar (in nests) in the limestones at Gaddankeri (Guddunkeeree) on the Kaládgi road, 5 miles south-west-by-west of Bágalkot. Lieutenant Aytoun considered the calcspar to occur as a dyke, the linear extension of which he was unable to trace because of thick overlying soil.

From here he travels westward, passing over a tract covered with laterite, the iron in which he supposes to have been derived from the underlying sandstones and blue schists (purple shales) into which it was infused by the plutonic agency which elevated this region. His sections of this part are merely vague outlines, shewing nothing of the stratigraphical position of the various formations.

He recognised the fact that the upper quartzites (forming his fourth sandstone range) to the south of the Bágalkot valley overlies the limestones and shales conformably, while both Dr. Christie and Captain Newbold had thought that an unconformity existed between them.

His theory of the volcanic origin of the breccias was arrived at by studying one of the sections in this quartzite ridge, and seeing to what an extent some thin beds were comminuted by excessive jointing. He conceived it possible that convulsive movements then supervening might mix up these fragments with the associated clays, and thus produce a clayey silicious breccia.

It is very hard to understand what difficulty Mr. Aytoun found in recognising the stratification of the sandstones of the Badámi and Jalihal hills, for it is remarkably clear and distinct as a rule, though the beds are of great thickness and often of very coarse texture.

The subaerial talus of sand derived from the degradation of these coarse sandstones was thought by him to be due to the action of some river not now in existence.

His description of the Kaládgi valley is fairly accurate, but his section No. 9 is a mere diagram, and quite wrong as to the position of the Deccan Trap as shewn above, when referring to section 1. In conclusion, he mentions the occurrence of green copper stains on surfaces of the limestones near Kajadoni, south-west of Kaládgi, and speaks of possible causes for the paucity of the supply of that metal.

Two minerals, which, according to the list appended to his paper, are very common in the lateritic region above referred to, namely, pyrolusite and psilomelane, were only observed by me in very small quantities as films or thin coatings or minute veins in laterite and hæmatite fragments.

Another paper by Mr. Aytoun, referring partly to the country under report, had been communicated the year before (*i. e.*, 1852) to the Bombay Geographical Society, the title of which was "Geological structure of the basin" of the Malprábha in the Collectorate of Belgaum,

including the Gold District. After pointing out the principal topographical and geological features of the basin generally, he addresses himself specially to the country around Bail Hongal, and describes the numerous hæmatitic silicious schist beds which occur there and south of the Malprábha near Belowaddi. Chloritic and red argillaceous schists are occasionally seen between the hæmatite beds, the whole much covered with regur, through which run the streams which prove auriferous. Much greenstone occurs in the valleys between Bail Hongal and Belowaddi. (Much of this greenstone is a massive, granitoid, chloritic rock.) He does not say which of these is the source of the gold he found, nor does he here say how trifling was the quantity he obtained by washing.

Dr. Carter, 1854.

Dr. Carter's Summary of the Geology of India* which was presented (to the Bombay Government?) in August 1853, and published in the Journal of the Bombay Branch of the Royal Asiatic Society for 1854, and reprinted in the volume of Geological papers on Western India, contains numerous references to the South Mahratta Country, based upon the writings of the several geologists already named, but little or no original information. He tried to correlate the formations then known with the provisional classification of Indian rocks he had proposed.

Some of the rocks in the Kaládgi basin near Bágalkot, as also some in the gneissic valley north of that place, and some "slates interlaminated with grey wacke" observed near Kaládgi by Dr. Christie, were classed under the head of "Cambrian and Silurian rocks" of M'Clelland.

The limestones of the Bhima basin at Ferozábád, as well as those of Kaládgi, are supposed to belong to the "Kattra Shales," while the basement beds of the Kaládgi series exposed in the scarps over which the Ghatprábha falls at Gokák are set down as "Punna sandstones" resting on the limestones and shales.

* The full title of this valuable contribution to Indian Geology is "Summary of the Geology of India, between the Ganges, the Indus, and Cape Comorin, by H. J. Carter, Esq., Assistant Surgeon, H. C. S., Bombay." The foot notes bring the information up to 1857.

With regard to the Deccan Trap, he considers on the authority of Captain (late Colonel) Meadows Taylor that there are large tracts of trap mud, including blocks and nodules of basalt, on the south-east boundary of the trap area between the Bhima and Krishna rivers; such flows belong to the second series of his Trappean system—a conclusion based on theoretical considerations only, and opposed to the real facts of the case, which are simply this, that the flows have been largely changed by weathering into an earthy mass, from the surface of which the yet unweathered basaltic nuclei protrude.

With regard to the laterite or iron-clay capping the trap rocks, Mr. Carter is favorable to Dr. Voysey's idea of its being a product of decomposition *in situ*. He does not, however, draw any distinction between the high-level laterite (iron-clay) in the Deccan, and the low level laterites of the Konkan, despite the immense difference in altitude between their respective positions; indeed he considers the Ratnagiri laterite also to be a true decomposed trap, not a detrital rock like the laterite of Travancore.

The blue clay underlying the low-level laterite at Ratnagiri, he considers identical with the eocene beds discovered by General Cullen; this conclusion is based on the similarity of situation relatively to the general configuration of the coast, and upon lithological identity of the blue clays and enclosed lignites and resins.

The theory of the trappean origin of the regur, or black soil, which he most strongly advocates, is not supported by, if not indeed positively opposed by, the circumstances under which the regur occurs, not only in the South Mahratta Country, but throughout the southern half of the Peninsula.

Greenough's Geological Map of India, 1855.

In 1855 a general geological sketch map of India compiled from various sources by George Bellas Greenough, a distinguished Fellow of the Geological Society of London, was published by his literary executors, *in memoriam* as it were

of the earnest student. It may, however, be questioned whether they would not have consulted his geological reputation much better by leaving the maps unpublished; for it is so faulty and incomplete geographically, that the imperfect geological information it contains becomes all the more misleading. The way in which the geology of the South Mahratta Country and South-Western Deccan is shewn is no exception to the rule; it is at best but a very rude approximation to the truth. The boundaries between the several formations could have been laid down much more closely from the notes of Captain Newbold, Lieutenant Aytoun, and other observers. The extensions of the Kaládgi sandstones across the Malprábha river toward Gajendragurh (Gudjunturgurh), which were mentioned by Christie, are completely ignored. The boundary of the Deccan Trap is made to coincide with the (left) north bank of the Ghatprábha river, though Newbold described a broad band lying to the south of that river and mentions its occurrence at Belgaum. The two singular loopings of the Krishna river at Jal Drug (Jal Droog) and of the Malprábha at "Purshgurh" are simply blunders in drawing. There are numerous other errors which it would be too tedious to enumerate.

Colonel Meadows Taylor, 1862-63.

The latest contribution to a knowledge of the geology of our area is a paper by the late Colonel Meadows Taylor, C.S.I., which appeared in the Journal of the Geological Society of Dublin* with the title of "Sketch of the Geology of the District of Shorapoor, or Soorpoor," in the Deccan. In this very interesting paper Colonel Taylor gives a graphic description of the beautiful gorge of the Krishna river at Jal Drug, which extends for

* Vol. X, 1862-63. It has been a source of much regret to me that I did not become acquainted with this sketch till after I had completed the survey of the region it deals with. Colonel Taylor resided long in that quarter, and had ample opportunities for making himself closely acquainted with all the beauties of the country, to which his sketch affords a capital guide. His memory is held in great regard by the people, who made many enquiries about him.

two miles from the fall of Chaya Bogavatti through almost blood-red granite (syenite gneiss). The whole is wonderfully grand and picturesque.

He describes the small plateau (or massive) of granite gneiss at the north-east side of which the strong fort of Shahpúr is built, and which attains an altitude of about 520 feet above the plains around. The Soorpoor hills are also described, and several of the very remarkable tors of granite gneiss occurring on them are figured, as also some occurring at other places.

He supposes the "granite" to have intruded partially into the limestone, and to have altered the sandstones and limestones at Tirth (Teertu) and Rajah Kollur by heat. This view appears untenable, the truth being that the sandstones and limestones (of the Bhima series, which alone concerns us here) were deposited upon and around many considerable elevations of the old surface of the granite gneiss. The heat evolved in the crushing up of the strata at Tirth by a fault and dislocation, would be quite sufficient to account for the trifling changes induced in the sedimentary beds.

The ridge of schistose gneiss running north-north-east from Bomanhal (Boarunubal) is described, and attention drawn to the veins of quartz containing black tourmaline in three-sided prisms which occur on, and to the east of, the ridge running parallel with the strike of the beds for several miles distance.

Turning to the sandstone series, he notices the fine cliffs of sandstone occuring at Gajendragarh (the extreme south-east corner of the Kaladgi basin).

The limestones (of the Talikot series) he conceives to be the Kurnool (Karnul) limestones of Newbold. He could find no fossils in them. He described the peculiar characters, and remarks that they are poor for lithographic purposes because containing too much silica.

He notices, also, certain small cylindrical cavities (tubes) in the limestones, the work of pholades according to Drs. Carter and Buist.

The occurrence of pyrites in the limestones north of Mudanur (Moodanoor) in sufficient quantity to be used for conversion into sulphur for the manufacture of gunpowder is likewise named.

Some of the Deccan trap-flows, in which unweathered, or but slightly weathered, nuclei of basalt appear in a matrix of soft wacké, he regarded as flows formed out of the condition of "volcanic mud" which had gathered up fragments of older flows in its wave-like course. He was acquainted with a large bed of supra-trappean chert, apparently that occurring at Shellugi near Talikot.

He describes some warm springs occurring in the Shorapur Taluq; one at Wajal (Wujul), and two at Mudanur.

The interesting brine springs at Bychubal, said to be sunk to a depth of 120 feet, are also described, and the remarkable brackishness of the water of the Don River is likewise referred to.

Colonel Taylor's admirable description of the fall of Chaya Bogavatti during a fresh has been noticed in the introductory chapter.

CHAPTER III.

GNEISSIC ROCKS.

The gneissic or older metamorphic rocks which occur in the South Mahratta Country, occupy, as a glance at the accompanying map will shew, mainly the western, southern and eastern portions of our area. Whether they all belong to the same age, geologically speaking, or whether future and more exhaustive examination of them will lead to their being sub-divided into groups of different ages, cannot be at present decided, nor need the subject be further entered upon here, although it is extremely probable that they will admit of being sub-divided and classified.

Principal inliers.

There are several noteworthy inliers of these ancient rocks, exposed by denudation of the younger and overlying formations. Among these are, though small in size, two hæmatite-schist inliers west of Amingarh and Kamatgi, on the right and left banks of the Ghatprábha river, between longitudes east 75° 40′ and 76°. These protrude through the Kaládgi series, the oldest post-gneissic rocks of this region. Besides there are the Kathárigarh (Kuttargurh) inlier, thirty miles east of Belgaum, and the Halki and Budnur (Boodnoor) inlier north of the Belgaum-Kaládgi road. West of these are the Wunnoor and Páchápur (Padshapur) inliers.

To the north of these are other three inliers, which may be distinguished as the Kelvi, Mamdapur and Gokák inliers.

Further to the south-west are two inliers in the valley of the Belgaum nallah. Westward of Belgaum and close to the village of Patna are two small inliers showing through the Deccan trap.

Two small inliers of granitoid gneiss appear protruding among the sandstones and quartzites of the Kaládgi series at foot of the Phonda Ghát.

Turning eastward thence, no gneiss inliers are met with for a distance of a hundred miles; then at a little to the east of Jamkhandi a narrow band of granite gneiss is traced between the foot of the Jamhandi hills (Kaládgi conglomerates and quartzites), and the Deccan trap occupying the valley of the Krishna. Ten miles to the south-east there is another small inlier at Bisnál occupying a similar position.

On the north or left bank of the Krishna, a few small inliers of gneiss show between the trap and some small inliers of Kaládgi rocks to the west of and at Mundapur.

Three inliers of gneiss occur in the area of the Bhima series: one ten miles east-north-east of Muddebihál (Moodebihal); a second at Salwárgi, ten miles east of Tálikot; and a third of considerable size close to Sháhábád station on the Great Indian Peninsula Railway.

Arrangement in bands of granitoid and schistose rocks.

The gneissic series includes a very considerable variety of rocks, schistose or granitoid, separated, as a rule, into great bands which may be traced in many cases for miles and miles across country. These bands are often very clearly, indeed sharply, defined, but yet it has been found very difficult to ascertain the relation subsisting between many of them. The rocks are often so much crumpled and distorted, or have been so greatly metamorphosed, that their bedding cannot be made out.

Many of these bands of schistose or granitoid rocks can be traced from the southern boundary of the younger azoic rocks or of the Deccan trap, southward across the great plains of the Raichur Doáb, and of Dharwar districts to the banks of the Tungabhadra river, which they cross, and stretch away into the as yet unexamined parts of the Bellary districts and Northern Mysore.

Prevalent strike.

The prevalent strike of these great bands is north-west-by-north; but this is not constant, and considerable areas are met with where other directions are followed by the lines of bedding. Thus in the eastern part of the gneiss area, the

strike ranges mostly from north-by-west to north-north-west, and south-by-east to south-south-east. This strike prevails as far west as the line of hills running south from Jalihal to Maski (Mooski), and passing down into the great cotton-soil plain west of Sindanur. To the west of this area near Ling Sugur is a belt of schistose rocks striking north-by-east, followed by an area of some three to four hundred square miles in extent along the Krishna, and northward to the edge of the overlying younger rocks near Muddebihál, throughout which the strike is most frequently east to west, or varies but a little north or south of that, as the case may be. South of this area is a very considerable district over which the strike is markedly north-west and south-east.

This south-east strike extends southward beyond the area surveyed. To the east it extends to within a few miles of the north-north-west strike prevailing over the eastern part of the gneiss region. To the west it extends as far as the great band of granitoid gneiss, which stretches from the Tungabhadra past Kanagiri and Tawurgiri to the south-eastern corner of the basin occupied by the Kaládgi rocks. This granitic band has itself a north-west and south-east strike.

West of this great band very little of the gneissic rocks can be seen in the Dharwar plain; but where schistose or other well-bedded gneissic rocks show at the surface, as at Nargund and Chik Nargund, the strike is almost invariably north-north-west varying to north-west-by-north. This strike of the bedding is also seen to prevail much further to the north in the Halki, Wannur, Mamdápur and Gokák inliers before enumerated. The beds shown in these inliers are northerly extensions of those occurring at and to the east of Bailhongal (Byl Hongul) in the Upper Malprábha valley. Among them are several conspicuous hæmatite-schist beds which, with others parallel to them, extend with a change of strike to south-eastward to Kittur and Dharwar. A similar change of strike appears also in cases of the southerly extension of the Nargund beds, which re-appear in the Dambal hills near Gadag (Gudduck).

West of the Dharwar-Belgaum road, the gneiss is greatly obscured by lateritic or lithomargic surface deposits, and beyond these, near Khánapur, a broad belt of granitoid gneiss, the bedding of which is doubtful. Westward beyond this granitoid band is a great development of very schistose, chiefly micaceous, gneiss, with some very thick beds of crystalline limestone, the strike of which is difficult to indicate, as the beds roll about greatly at very low angles.

These beds shew much the same position in the several sections at Talewári Ghât, and Bhimgarh, and in the Tillar ravine.

The gneissic rocks in the Sawunt Wari and Ratnágiri Konkan which were examined by Mr. C. J. Wilkinson, late of the Geological Survey of India, are very varied in kind, more so a good deal than those in the Deccan, comparing area with area, and their distribution appears not to occur in such distinct bands. The several rock varieties also occupy relatively much smaller areas in the Konkan than above the ghâts. South of the Tillar river, the dip of the beds is generally north-easterly; while to the north of the river south-easterly dips are more prevalent. In the central part of the gneiss area the beds have often southerly dips, while in the western and northern parts the bedding shews numerous foldings with a north-north-westerly or northerly strike.

In the southern part of the Konkan country, they form spurs and hills of great height, little inferior in elevation to the ghâts themselves; as for example, the spurs branching from the Sadda promontory of the ghâts and the Pargarh, Bhekurlé and Hammantgarh spurs. Further north, as the trap region is approached, the gneissic rocks shew signs of their having been greatly denuded and reduced to a great plain by marine denudation anterior to the deposition of the Kaládgi series which lie upon that plane surface.

The principal varieties of the gneissic rocks described by Mr. Wilkinson are, true gneiss, micaceous and hornblendic schists, older quartzites and altered micaceous sandstones, together with some sub-

ordinate bands of granite, and syenite gneiss. Besides these, he mentions talcosee and chloritic schists, also actinolite schist, which is very rare in the Deccan. Crystalline limestones appear to be entirely wanting, except on the Talewari ghât, and there they only just descend low enough to be reckoned as partly in the Konkan.

Two groups,—Granitoid and Schistose.

The rocks met with in the gneissic series are divisible into two great groups,—the *granitoid*, highly crystalline and massive, and the *schistose*, less crystalline and often highly foliated and distinctly bedded, but each of the groups includes a considerable number of distinct and well-marked rock varieties, many of which deserve special notice. The association of these rocks in distinct and separate bands has already been mentioned.

The granitoid group.

The granitoid group includes granite-gneiss and syenite-gneiss in many varieties, some depending on the predominence of one or other of the constituent minerals, others upon the difference of texture, whether coarsely or finely crystalline or porphyritic; and as usual there are many cases of transition from one into the other, not only between the varieties belonging to one or other of the two great groups, but also of the members of one group passing into rocks included in the other.

The Raichur granite gneiss area.

The granitoid group occupies a greatly larger extent of surface within the area to which this report refers than does the schistose group. The whole of the eastern part of the gneissic area shewn in the accompanying sketch map is, speaking generally, occupied by highly crystalline and massive granite gneiss in all its varieties.

Maski schistose band.

Only a few unimportant bands of hornblendic or micaceous schist are to be seen in the country stretching from the Raichur group of granitoid hills westward to Gallag and Jálihal, and extending south-west tó near Sindunur and

north-west to the Sorapur and Shahpur (Shawpoor) hills, to the westward of which is a great band of schistose rocks which I will call the Maski (Moosky) band, after the large village of that name which stands on the band in question.

In the north this granite-gneiss area reaches up to the limestone plain of the Bhima and Kogni valleys, and to the south it stretches away far into Bellary District.

Mudgal-Jaldrug granitoid band.

Westward of this great spread of granitoid gneiss rocks, they recur again in several bands with intermediate bands of schistose rock. The first of these proceeding westward is the Mudgal- (Moodgul) Jaldrug band, which joins the hills round the former place (an important town and fortress in mediæval times, and a great bone of contention between the Musalmans of Bijapur and the Hindus at Bijanagar), and the group of bold hills through which the Krishna has cut the fine gorge at the head of Jaldrug island.

On the north bank of the Krishna river this granitoid band extends itself to the north-eastward, and apparently joins the granitoid mass of the Sorapur hills, which belongs to the Raichur granite gneiss area.

Hunugunda schistose band.

Westward of this Mudgal-Jaldrug granitoid gneiss band is a remarkable and well-defined band of schistose rocks about eight to twelve miles broad, running north-westward from the town Tawurugiri till it disappears under the eastern edge of the Kalàdgi basin. This band of schistose rocks may conveniently be called the Hunugunda (Hoonoogoonda) schistose band. Westward of this is a broad band of granitoid rocks striking equally in a north-west direction, and extending up to and under the south-east end of the Kalàdgi basin and its numerous outliers to the east of the Malpràbha river. The western extension of this

Kushtugi granitoid band.

granitoid band, which may conveniently be designated as the Kushtugi band, is hidden by the great cotton soil spread covering the Dharwar plain;

but granitoid rocks are seen at Belur, Jalihal, and at Bidinaganur in the valley of the Benni-halla, the principal southern affluent of the Malprábha.

Nargund schistose band.

Schistose rocks appear at Nargund and Chik Nargund and also at Saundatti (Sumoduttee).

Kathárigarh granitoid band.

Beyond these, near Assúndi, is another band of granitoid gneiss which crosses the Malprábha and reappears in the Kathárigarh (Kutturgurh) valley.

Bailhongal schistose band.

A very broad band of schistose rocks lies in the upper valley of the Malprábha westward of the Kathárigarh granitoid band. This band, which may be called the Bailhongal (Bylhongul) band, extends to within a few miles of the Taluq town of Khánapur, where it joins the most westerly band of granitoid gneiss.

Khánapur granitoid band.

This is not an important band. It forms some conspicuous hills at Gani Bail (Gunehbyle), twelve miles south of Belgaum, and passes south through Khánapur to the Nandgarh hills.

Special features of granitoid gneiss areas.

The peculiar characters of granitoid rocks are admirably developed in many parts of the several bands, but nowhere are they better seen than in the Sorapur and Jaldrug hills. In the former they form many very remarkable tors of great size and beauty, equal in extent and strangeness of shape to the most celebrated Cornish or Devonshire examples. Several of these have been figured by Colonel Meadows Taylor in his paper quoted at page 34.

In the last-named hills, and especially near the Krishna river, there is much beautiful rock scenery, the hill sides being often thickly overgrown with small trees and thorny creepers of great size, whose green foliage sets off the rich red or pinkish color of the rocks to the greatest advantage. One scene of very great beauty occurs at the little village of

Raianphalli (Ryanphalli), where among the rocks, which rise two or three hundred feet sheer above the valley, is a small tank of pure blue water which perfectly simulates a real mountain lake. The great masses of granitoid gneiss rise in castle-like masses, and many fine trees round the village complete the beauty of the scene.

In many other places, also, the wildness of the rocky granitoid hills gives rise to interesting, and, here and there, even beautiful scenery, as at Mudgal, Maski (Moosky), Bhanur (Bhunoor), Deo Drug, and Raichur in the Doab, and in the Sháhpur (Shawpoor) hills between the Krishna and Bhimas, and the Yadgiri (Yedageery) and other hills to the east of the Bhima.

By far the commoner type of the granitoid gneiss is a more or less porphyritic rock consisting of quartz, felspar, and hornblende in varying proportions. The felspar very frequently predominates. Micaceous granite gneiss, though less largely developed than the hornblendic variety, occurs over considerable areas, *e. g.*, near Raichur in the Sháhpur (Shawpoor) plateau, and eastward between the Bhima and Krishna rivers; to the north of Hanam Ságar (Hunum Sagur) and various other places besides.

Obscure bedding.

As a rule, the granitoid varieties are not distinctly bedded; indeed very frequently the bedding is entirely or very nearly obliterated.

Distinct bedding.

There are places, however, where it is distinct enough to allow of the true dip and strike of the rock being determined and even measured. Such is the case in the fort hill at Mudgal. Here the rock, though perfectly crystalline in texture, has a distinct north-north-westerly dip at an angle of 10°. The lamination of the rock is generally obscure from its homogeneous color, but it is sometimes very distinct, and in one case I observed distinct, diagonal foliation, or "false bedding."

Transition to schistose varieties.

The transition from the highly crystalline massive form to distinctly bedded and even schistose rocks, is often to be seen near the boundaries of the granitoid areas. The granitoid gneiss in those cases shews a broadly banded structure, the bands being parallel to the true foliation of the less altered rocks, and being in fact the true layers of original deposition. In many cases such banding is met with even in the main granitoid masses far away from any point of transition, and the banded parts of the rock often present the appearance of being enclosed masses of a foreign rock, though in reality they were only parts less completely metamorphosed than the main mass. Such transitions may be seen and studied to great advantage at various places within the gneissic area; for example, along the eastern base of the ridge forming the Maski hill, and at Kotapur near Kautala (Civital), the former in the Mudgal, the latter in the Raichur taluq.

Examples.

Red syenite gneiss.

A remarkable variety of syenite gneiss, noticeable because of its great beauty, was seen on the south bank of the Krishna just opposite to the Jaldrug (Juldroog). This rock, which is very porphyritic in texture, is of bright red color, and has taken a very high polish on many of the rocks in the bed of the river. The red color is owing to the great predominance of the red felspar it contains. The hornblende is greenish black. A very similar rock forms the Péla-konda (Pailpenta) hill or "Bell rock," a very conspicuous rocky hill south-west of Ling Sugur cantonment. The rock is of a bright red color, and largely traversed by films and veinlets of bright yellow green pistacite. It rises out of the pale pinkish grey "blotchy" gneiss of the neighbourhood, as if an irrupted mass, but there is no positive evidence of its being such.

Another remarkably handsome variety of porphyritic syenite gneiss, in which dark green hornblende and dark salmon-colored or brownish-pink felspar unite to form a stone of very rich color, occurs at Gajendragarh underlying the extreme south-eastern end of the Kaládgi series.

Remarkably porphyritic varieties of syenite gneiss were observed at Bandora on the left bank of the Krishna river, ten miles south-west of Sorapur, and at Hosur, a little south of Jálihal. In the former case the mass of the rock was red, in the latter dark-greenish grey.

Color of weathered rocks influenced by lichens.

Many of the hills formed of granitoid gneiss are characterised by showing generally on their summits, but sometimes also on their flanks, areas in which the assemblage of weathered blocks and tors is of much darker blackish-brown to almost black color than the general surface. Very frequently, if not generally, these dark, highly "blocky" areas show much more rugged surfaces than do the adjoining parts, though made up of blocks of the same size and character. In many cases this darker colored assemblage of blocks appears to form a capping to the hills formed as it were of a younger intrusive rock trappean in character, that had been poured out over the granitoid gneiss, and certainly present that appearance when seen from a distance.

There are, however, no lines of demarcation between the two rocks when closely examined, and the darker color seems to be external only, for when chipped with the hammer they are found to consist of the same, or an almost identical variety of very compact grey quartzo-felspathic granite gneiss, as in the adjoining lighter-colored blocks. Mr. King, who examined the hills south of Raichur, where this curious structure is largely developed, especially in the hills crowned by the ruins of the old Malliabad Drug, was inclined to think the dark-colored assemblages of blocks might be the fragmentary remnants of overlying beds, differing but little from the underlying ones, excepting in that they weathered of a dark instead of a light color. Various hills in the northern part of Bellary districts and in the Raichur Doab, which exhibit precisely the same structure, were very carefully examined by myself with no satisfactory result at the time, but I have since then come to a different conclusion. I could detect no connection between the different external colors and the bedding of the rocks; the dark or light color

seems to depend entirely upon the presence or absence of a very minute black lichen, which specially affects the highest, most inaccessible, and most weather-beaten parts of the rocky hills, but only when the surface is much broken up by excessive jointing. The excessive development of jointing probably depends upon some local difference in mineral character not appreciable to the unassisted eye, but which doubtless favors the growth of the black lichen. The dark coloring may be seen in some instances recurring at intervals in different parts of one and the same bed of the granite-gneiss. A similar lichen occurs also on some of the larger trap dykes, the summit ridges of which are excessively broken up. The presence of trees, or the transit of much drainage water over the surface, prevents the homogeneous covering of the surface by the lichen in question, and hence its great development only under the circumstances described.

The schistose group.

The schistose members of the gneissic series occupy, as already mentioned, a much smaller area in the country under description than do the massive granitoid varieties, but still they form very important features in various parts, and are deserving of much more study than the time at my disposal admitted of.

Five varieties.

Five principal varieties must be noted among them; they are, 1*st*, hornblendic schists; 2*nd*, micaceous schists; 3*rd*, chloritic schists; 4*th*, hæmatite schists; and 5*th*, talcose schists. The order they are given in represents very fairly their relative importance as measured by the areas they occupy respectively.

Hornblendic schists.

The most important and largest development, superficially, of the hornblendic rocks is that which occurs in the Maski band of schistose gneiss. By far the greater part of this band consists of hornblendic schists of different sorts, but with them, and apparently passing into them by slow and almost imperceptible gradation are various beds of chloritic and a few of talcose schist. Some beds are rather deficient in hornblende and very

argillaceous, so that they are really hornblendic clay schists rather than hornblende schists.

Form of hills in schistose areas.

In general features these schistose areas differ from the granitoid areas by the much greater smoothness of their surface, for even when they form hills they are in most cases gently rounded in form, and rarely shew very rocky surfaces. The slopes of the watersheds are, however, greatly cut up and worn into very numerous small rounded hillocks. Few conspicuous hills exist in these schistose districts, and the scenery is very rarely anything but commonplace and monotonous. This is in great measure owing to the very scanty vegetation by which the schistose rocks are covered. This paucity of vegetation is particularly noticeable in the hilly tracts north of Maski (Moosky) and Kautála (Civital). The more slatey the schist, the more barren the hill sides. It is only when a thick bed of cotton soil covers the schists that the country is fertile. In some few places, however, the schists weather into a bright red soil, which is very fairly productive.

The second most important development of hornblendic schist occurs in the south-eastern part of the Hunugund schistose band, especially near Bhogapur Ulugundi (Bhogapoor Oolugoondi) to the north-east-by-east of Tawurugiri, where it forms a considerable hill very conspicuous by the intense blackness of its bare and rocky sides.

Micaceous schists.

Micaceous schists are but little developed in the eastern and central portions of our gneissic area. In the western, on the contrary, they are largely developed, and form the principal mass of the older rocks on which the southern extension of the Deccan trap rests in the Western Ghâts. The micaceous schists are here seen in vast thickness, and superbly exposed in the grandly beautiful ravines of the Mahadayi (Madwee) and Tillar rivers, also in the scarps south of the Parwar and Ram Ghâts. The micaceous beds are soft, and weather away more readily than the overlying basaltic flows;

J. Schaumburg, Lith.

DRY WATERFALL EAST OF CARWÁR GHAT.

hence there are frequently small caves and overhanging ledges at the junction in the two rocks, especially at the points where cataracts fall over the scarps in the rainy season. One very fine example of this occurs on the north side of the Tillar gorge, a little to the north-west of Kolik (Koleek). The action of the fall on the soft micaceous rock has eaten a large cave into the mountain side just below the lowest trap flow. Thick jungle grows up into the wide crescent-shaped mouth of the cave, while the falling water, as seen from the opposite side of the ravine, hangs like a waving silver thread across the dark yawning space and falls among the trees below. The basaltic cliff overhanging the cave is so sheer that it is probable nothing can be seen of it except from the opposite side. I much regretted that want of time prevented my exploring the cave itself, when working on the northern side of the great Tillar ravine. It must be a very interesting spot, and probably also a beautiful one. Many beautiful clefts and gullies of great depth are to be seen in other places, as, for instance, from the Parwar Ghát, one very fine example of which is here figured (Plate I).

Caves and gullies.

Chloritic schists, generally of very delicate pale sea-green, are met with largely at many places in the Hunugund schistose band, *e. g.*, at Somulapur, ten miles south-west of Mudgal, at Timapúr (Teemehpoor), three miles north-west of Hunugund, and at various other places along its north-west extension. Chloritic schists of similar pale color are also met with largely in the Bail Hongul schistose band. They occur interbedded with and passing into a similar pale-green massive chlorite rock of semi-crystalline texture, which in some places assumes in its weathered state a singularly trappoid appearance. In other places this is the more general character, the weathering bringing out the schistose texture of the rock. This rock has been regarded by previous explorers as a true trap, but I think erroneously. From its position and mode of association with the schistose beds, the passage into which is very frequently to be seen, it appears to me

Chloritic schists.

to be merely a product of a locally more intense metamorphic action, such as much of the granitoid gneiss unquestionably is.

Dark-green colored chloritic beds are also frequently met with, but they are less common and certainly much less conspicuous than the beautiful pale-green variety.

The chloritic schist tracts are characterized by the absence of all hills of any size or elevation, but are much cut up on a small scale by water-courses.

Hæmatite schists.

The hæmatitic schists are a series of often richly ferruginous silicious schists which take in this part of the Peninsula the place that is occupied by the magnetic iron beds of the Salem, Trichinopoly, South Arcot, and Coimbatoor Districts further south, and, like these latter, from their greater hardness, frequently form conspicuous features in the landscape, rising into long, rocky ridges of considerable height and mass. The silicious laminæ of the rock are generally very fine-grained and often as semi-vitreous in texture as true quartzites. Their color varies from nearly white to bright red or even dull brownish-purple. The true foliation or bedding of the rock is almost invariably perfectly preserved. The amount of iron in the form of rich red hæmatite varies very much in different parts of the same bed even; a feature which is characteristic also of the magnetic iron beds of the south. In rich parts of the beds the ferruginous laminæ are entirely composed of the hæmatite, but in poorer parts the hæmatite contains many silicious particles, which increase in number, and finally, in the poorest varieties of the schist, predominate, so that the hæmatite appears merely as included grains. Occasionally the iron-ore disappears entirely, and for considerable distances the bed is then nothing else than a very finely laminated silicious schist of jaspideous texture, often approaching closely to fine quartzite in appearance. In some beds the silicious laminæ are all or in part stained red in varying degrees of intensity, ranging from pinkish to almost pure

Color and texture.

scarlet, which contrast very well with the purplish-grey of the richly hæmatitic laminæ and the whitish or pale-drab of the non-stained silicious laminæ. In many cases the bedding has undergone great contortion, and been crumpled into series of vandykes, in which the alternating bands of color are exquisitely displayed. Such has been the case on a considerable scale in the great hill two and a half miles west of Amingarh village in the Hunugunda Taluq, which is probably the finest display of these richly ferruginous deposits. The rocks at this place are generally very rich in hæmatite, and the red bands are very numerous, so that the great curves and minor vandykes in which the beds stand out from the hill sides present a very remarkable and, when lit up by the morning sun, a very beautiful appearance.

Great contortion of strata.

Amingarh beds.

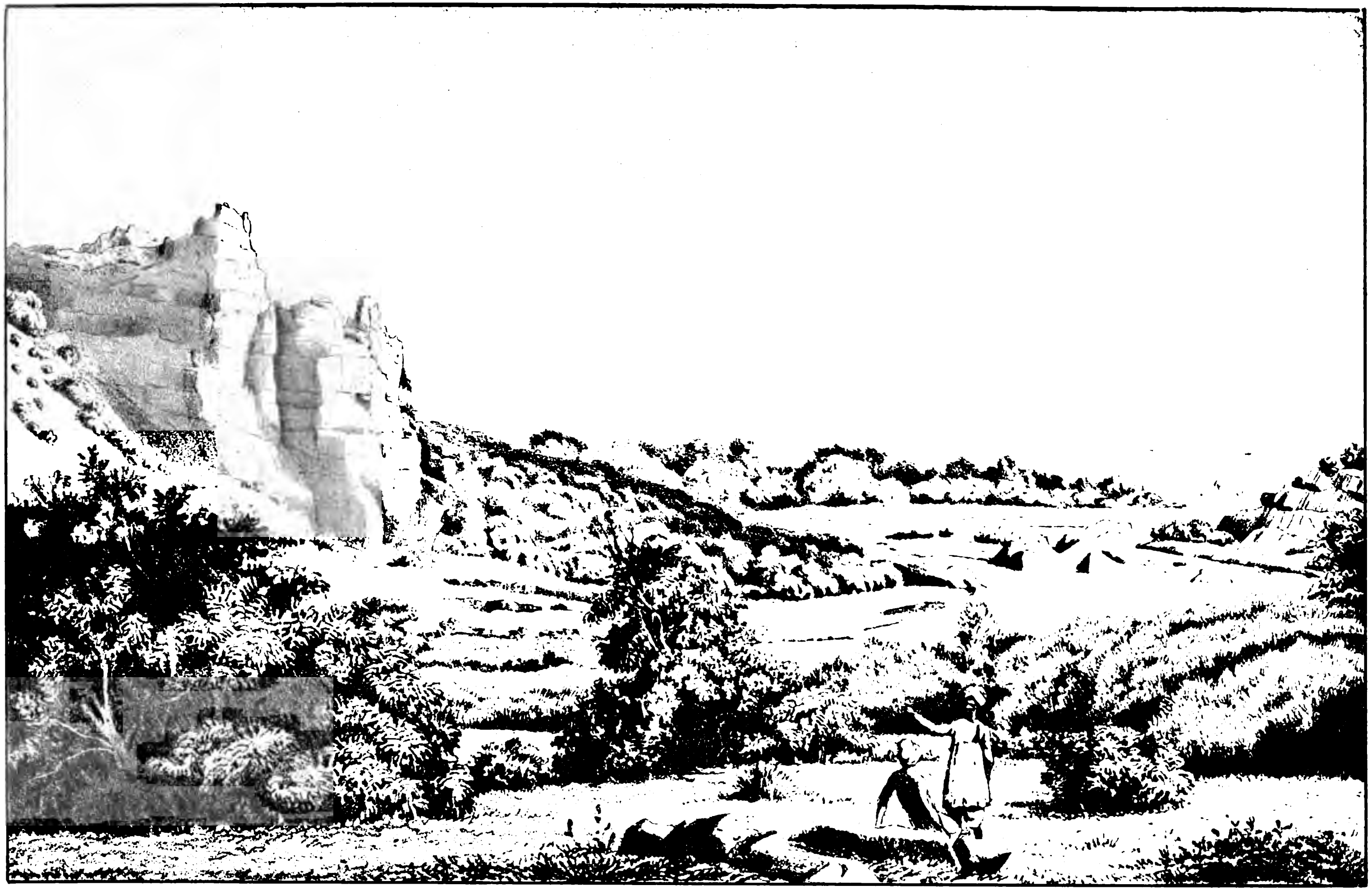
The principal hæmatite beds are all found in the Hunugunda schistose series. Besides the Amingarh hill beds above named are those of the Jiadigudda (Jeeadigoodda) hill near Tawurugiri in the Nizam's territory, which are of great thickness, and, near the summit of the hill, of very great richness, though they rapidly become poor further westward. In former times a very considerable quantity of ore from this place was smelted at Tawurugiri, and is reported to have yielded iron of the best quality, much sought after by the native armourers at Hyderabad and elsewhere. The iron industry has, however, now completely died out at Tawurugiri owing to the great rise in the price of charcoal caused by the extensive disafforestment going on over the whole Deccan. The Jiadigudda beds are the richest in hæmatite that I observed in the Deccan, or South Mahratta country. They form the backbone of the Jiadigudda ridge, which rises some 800 to 900 feet over the surrounding country and is the highest hill in that quarter. The beds stand up at a very high angle, and apparently dip southward, but I am inclined to suspect that the real structure of the ridge is an anticlinal, the arch of which has been denuded away.

Jiadigudda-Hunugunda beds.

The relation of the iron beds to the associated chloritic and hornblendic schists is locally very obscure. This hæmatite bed is unquestionably, I think, the same as that which again rises into a high and conspicuous ridge to the west of the high road from Tawurugiri to Ling Sugur, and may be traced still further north-west to the Kandagal hills (Kundagul), and on to Tumbigi (Toombigee), some nine miles further. It is then lost under a great spread of cotton soil, but another band of similar hæmatite-schists rises out of the cotton soil at the town of Hunugunda, which may very reasonably be regarded as the reappearance of the hæmatite bed traced from the Jiadigudda to Tumbigi. The Hunugunda ridge itself disappears under the vast cotton soil spread here covering the face of the country for miles around, and for six or seven miles no sign of the hæmatite beds can be traced till the Malprábha river is reached. At some distance from the left or western bank of the river, hæmatite-schist beds again appear in force and occupying a position such as perfectly to justify the assumption that they represent the Hunugunda-Jiadigudda beds. These beds, west of the Malprábha, form several hills near Hamblikop and Byranmatti (Byrunmuttee), and are manifestly continuous with the two great beds which disappear under the Kaládgi rocks, the northern one at the Karlimatti pagoda hill, the southern one a little to the south-west of

Yerkal cliffs.

Yerkal, where it crosses the Ghatprábha river. A very picturesque cliff of hæmatite-schist rises on the western bank of the river, but the band of which it forms part disappears under the basement quartzites of the Kaládgi series on either side of the river. From its position there can be but little doubt that this bed is a westward extension of that which first disappears under the Kaládgi rocks at the Karlimatti pagoda hill. The great cliff, as seen from the south, is shown in the accompanying sketch (Plate II). Except at the Jiadigudda and at the Meyrudodi Pagoda, some nine miles to the north-westward, this great hæmatitic band (for it can hardly be regarded as one bed) is nowhere rich in iron, and near Kandagal it differs from the others in becoming rather argillaceous in character.



J. Schaumburg Lith.

CLIFF OF HÆMATITE-SCHIST ON THE GHATPRABHA AT YERKAL.

The relations of the Amingarh and Hunugunda hæmatite beds were not determinable owing to the great spread of cotton soil lying between the two. They differ somewhat in character, the latter, excepting at the Yerkal cliffs being more schistose and less jaspideous in texture, and being much less stained with the red color so conspicuous in the Amingarh beds. Two inliers of the latter rise within the limits of the Kaládgi basin,—one a few hundred yards from the Amingarh hill, the other several miles to the westward near Kamatgi (Kummutgee) on the left bank of the Ghatprábha.

Bail Hongal series.

Numerous beds of hæmatite-schist are met with in the upper valley of the Malprábha in the Bail Hongal (Byl Hongal) schistose band. They differ in no essential respect from those above described, and except that they form conspicuous ridges among the softer schistose rocks there prevalent, they merit no special mention. As a rule, they are poor in iron, and but rarely show much of the red staining, though frequently jaspideous in texture. The country is covered with their *debris* to a remarkable extent. Minute quantities of gold are found in some of the nullahs in the Bail Hongal and Belowaddi townships, but they are so small that the sands are hardly washed now-a-days. No gold is known to accompany the numerous hæmatitic beds in the Kaládgi district and western part of the Raichoor Doáb. A moderate-sized hæmatite-schist bed forms a well-marked buttress on the south-east side of the Chik Nargund hill in Dharwar District. The bed, which is very rich and of dark purple color, dips east-by-north at a high angle; it belongs to the same series as those forming the lower portion of Pedda Nargund hills.

These hæmatite-schists are but very slightly if at all represented in the Konkan gneiss area, where their place seems to be occupied by quartzites and altered ferruginous sandstones which are of frequent occurrence, but do not form very conspicuous and important bands as they do in the Deccan.

Talcose rocks.

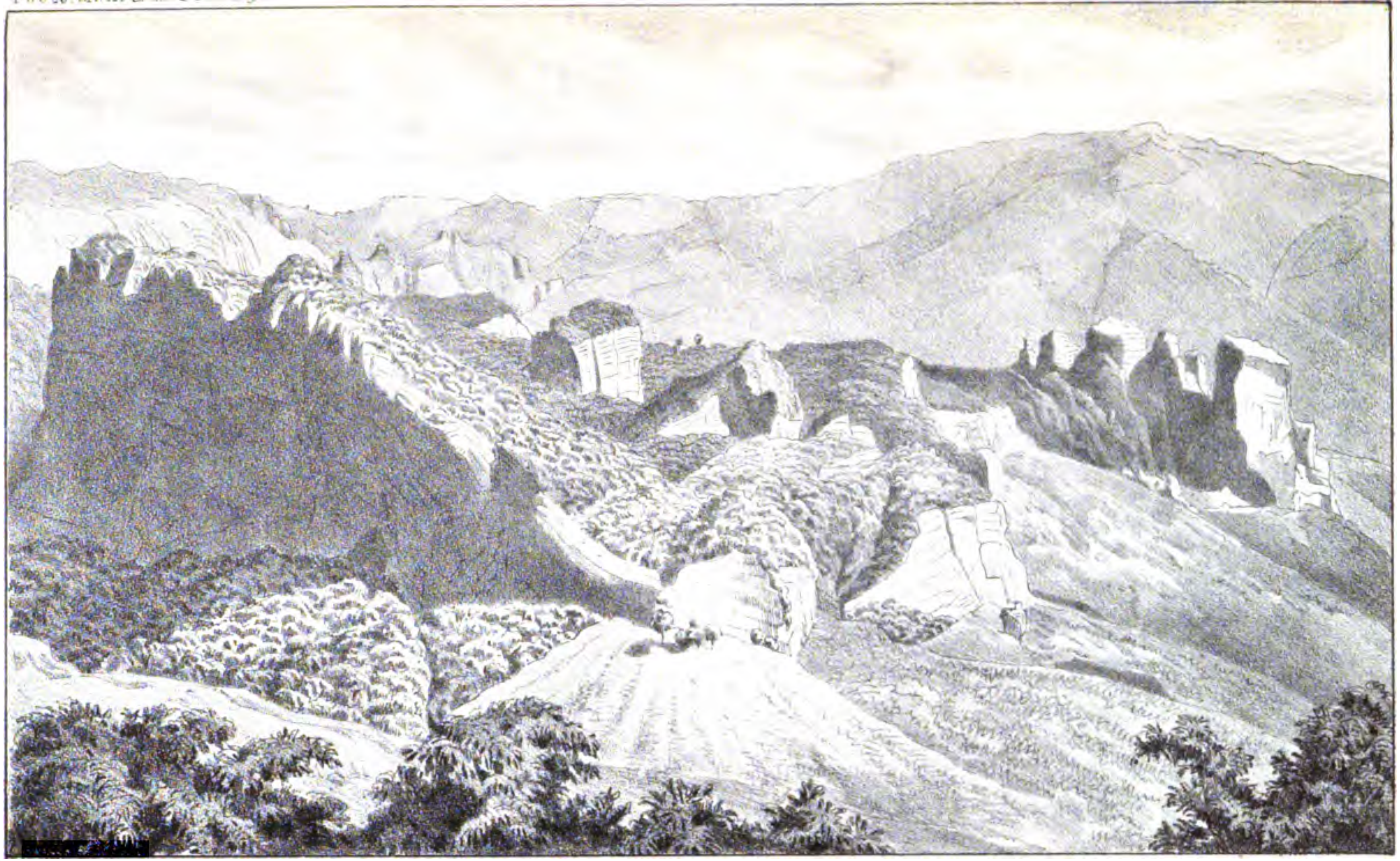
Of true talcose rocks but very little was met with, and in one place only in any quantity; this was at Todihal on the south bank of the Krishna river and fifteen miles north-north-east of Kalâdgi. Here several small beds of pale pinkish white talc rocks occur intercalated between beds of hornblendic gneiss.

Talcose schist.

Talcose rocks are much more common in the Konkan gneiss area than in the Deccan. Mr. Wilkinson found a hard blue talc rock in the bed of the Tillar river at the crossing of the Râm Ghât, Vingorla road. This rock decomposes into a light-colored soapy material. It is interstratified with compact dark-green hornblendic and mica schists, and is of some importance as the bed extends up into the spur lying between Sasoli and Komberil (Koomberle). Similar compact blue talc rock occurs near Akeri (Akoree) to the north-west-by-west of Sundur Wâri. At Bamburda, eight miles north-east of Vingorla, talc rock forms a hill capped by an outlier of the coast laterite. Schistose talc rock occurs at Pingul (Pingool) four miles north-north-west of Bamburdee at Bid Wâri at the northern end of the Konkan gneiss area, and on the south bank of the Assia Mat (Usya Mat) river between the village of that name and Wankda.

Actinolite schist.

Actinolite schist was noted by Mr. Wilkinson at four places in the Konkan, but none was seen by me above the ghâts; one occurrence of it at Nandawadagi, fourteen miles east-by-south of Hunugund, was noted by Captain Newbold. The actinolite schists observed by Mr. Wilkinson were met with at Kodal (Koodal), eleven miles north-west of Sundur Wâri, and at Pamburda, five miles north-east-by-north of Kodal. At Tulsuli (Toolsoolee), about three miles to the east of Pamburda, beds of actinolite schist and quartzite form the mass of a group of hills immediately west of the village. Actinolite schist, associated with quartzite and micaceous schists, occurs also between Kusal and Koonda six miles north of Pamburda.



J. Schaumburg, Lith.

MAGNESIAN LIMESTONE ROCKS SOUTH OF BHIMGARH.

Crystalline limestones.

Associated with the schistose members of the gneissic series are beds of crystalline limestones; they are rare, having been met with in only four places.

Dolomite.

The greatest development of crystalline limestone, in this case a dolomite or magnesian limestone, was noted on the western slope of the ghâts immediately south of the extreme southern point of the great Deccan Trap area. The dolomite here occurs underlying a series of flaggy, micaceous schists of rather soft and friable character. The dolomite which is much harder and occurs in bed of great thickness, remains standing out in bold rocky masses, some of them many hundred feet high, forming the most striking features of the beautiful landscape they help to form.

One of the most conspicuous of the masses is that on which stands the old Mahratta hill fort, the Bhimgarh, east of Goa. As seen from the north side of the great ravine of the Mahadayi (Maadwee) river, looking over the scarp formed by the edge of the trap area, the Bhimgarh, with an adjacent limestone peak and several huge masses which have slipped down into the valley, forms one of the wildest and most beautiful pieces of rock and forest scenery on a large scale that I have had the good fortune to see. My visit was unfortunately made about two in the afternoon, and the heat-mists were rising so rapidly that it was hopeless to attempt a sketch of this noble scene. The dolomite beds extend southward from the Bhimgarh across the Taliwari or Kell Ghât, and up the northern slope of the great Darshin Dongar, the highest mountain on the edge of the ghâts in this part. The annexed view (Plate III), photographically reduced from a large and very careful sketch made from the village of Bhimgarh, conveys a good idea of the noble forms into which the dolomite beds have there been carved by erosive forces.

The dolomite shows under the ghât laterite a little way down the slope on the north-east side of the Darshin Dongar about half or three-

quarters of a mile from the summit, which is the Pahldy Trigonometrical station of the map. The limestone here, as well as at Bhimgarh, is a light-grey sacharoid magnesian limestone with numerous laminæ of quartz showing the bedding of the rock very clearly.

An analysis of the dolomite in the Survey laboratory by Mr. Tween showed its composition to be—

Water and organic matter	4·
Carbonate of lime	56·4
Ditto of magnesia	34·8
Oxide of iron with a little alumina and manganese ...	3·6
Insoluble	2·2
	101·

Oxide of manganese in the dolomite.

Near the east gate of the fort a considerable quantity of a dark blackish-brown powder was observed to have accumulated on the surface of the dolomite from which it had evidently been weathered out. The limestone, the face of which was greatly concealed by vegetation, was here darker in color than in the main mass of the mountain. The mode in which the black mineral occurred in the unweathered rock was not clear, the rock being greatly obscured by dense vegetation, but I believe it occurs in the form of minute grains scattered through the general mass. An analysis of it by Mr. Tween showed it to consist of—

Water and organic matter	14·6
Oxide of iron and a little alumina	22·
Oxide of manganese	20·
Insoluble	44·8
	101·4

The other three occurrences of crystalline limestones were:—*Firstly*, a bed of grey crystalline limestone underlying the hæmatite-schist bed which forms the crest of the ridge south of Bail Hongal in the upper valley of the Malprábha. *Secondly*, a small out-crop of very silicious grey limestone forming a couple of small inliers in the Deccan Trap area four miles east of Nelseri traveller's bungalow on the Belgaum Kaládgi road. The *third* and last of the occurrences of crystalline limestone was observed at Guganhatti six miles north-east by-north of the second locality. A very considerable bed of grey limestone occurs there east of the village, associated with argillaceous and micaceous schists.

Intrusive rocks associated with the Gneiss Series.

1. Trappean rocks.

The foreign rocks that are found traversing the ancient gneissic series are of three classes: *firstly*, trappean rocks; *secondly*, granitic rocks; and *thirdly*, quartz reefs. Of these the trappean rocks, which occur in every case but one as dykes, are by far the most important, being both numerous and many of them of great size and length. Lithologically they show but very trifling differences; nearly all consist of basaltic diorite of dark-bluish or greenish-black color and moderately fine grain. A few dykes are porphyritic in their structure, and, from the greater quantity of felspar, they are grey or, more strictly speaking, speckled white and blackish (pepper and salt). Occasionally the felspar is of a green color, mostly of a pale hue.

Several are remarkable for their great size, such as the Gutt Bichal on the north side of the Tungabhadra opposite Cachapur, from which the greater part of the material for the piers the great Cachapur Railway bridge was quarried. This dyke is one of the important group which

stretches across the Raichur Doáb from the banks of the Tungabhadra near Cachapur to the banks of the Krishna at and near Jal Drug; members of this group rise in places into rocky ridges 200 or 300 feet above the plains and are conspicuous far and wide from their intensely black color. At other places they disappear under the soil (which over the greater part of the Doáb is regur, forming vast spreads) and are lost sight of for considerable distances. Several may be traced by the naked eye for many miles across the country.

The Doáb series of dykes.

The very numerous dykes occurring in the Raichur Doáb, and in the adjacent parts of the Kaládgi district, and in the Sorapur Taluq, (Nizam's Dominions), north of the Krishna, may in great part be assigned to several different groups or series, according to the direction of their courses. No distinction can be drawn between the several groups as to priority of ages, for in all the cases in which dykes were found crossing each other's course, they presented the appearance of being perfectly contemporaneous and of having been formed by the same act of intrusion from the same source filling up two or more fissures simultaneously. A number of the dykes, however, cannot be referred to any group in particular, while some vary considerably in the direction of different parts of the courses, which renders it difficult to know to what group to assign them. No lithological peculiarity was observed to attach itself to any special group. The principal groups are as follows:—

The Doáb Group: W. N. W. to E. S. E.

The *Doáb* group, so called because the chief members of the group may be traced, with only a few breaks, from close to the banks of the Tungabhadra right across the Raichur Doáb up to or across the Krishna river. The course followed by these dykes is generally west-north-west to east-south-east.

The great Gutt Bichal dyke before mentioned is a leading member of this group, which is also well represented near Kautala (Civital)

near Ling Sugur and Jal Drug. Dykes having the same course occur on the left bank of the Krishna, north of Sorapur, and westward close to the north-east corner of the Kaládgi basin, under which some of them are lost sight of.

Between Mudgal and Hire Mokartihal on the Bellary road and south of the central assemblage of members of the Doáb group near Ling Sugur is a minor but yet important assemblage of dykes, some of them of large size, pursuing a similar course, and therefore referable to this group.

Another important set, belonging to this group as regards the direction of course, occurs beyond the limits of this report in the northern part of the Bellary district.

2nd Group: W. S. W. to E. N. E.

The *second group* includes a considerable number of dykes, mostly second rate in point of size and length, whose course is west-south-west, east-north-east. To this group belong a set of large dykes at Sorapur; another set to the south-east-by-south at Mandurgi (Moondurgi) (which are doubtless continuous with several dykes north and east of Mosulkal), and a huge dyke, the Kiadigiri (Keeadigerri) dyke, about eight miles further south. This dyke on several points in its course rises into considerable hills, 200 to 300 feet high or more. A large dyke at Kunnusari, south-by-west of Mudgal, and a set of three dykes at Rolli on the right bank of the Krishna close to the Kaládgi-Sholapur road. Besides these are several other important dykes scattered about in various parts of the gneissic area.

3rd Group: S. S. E. to N. N. W.

To a *third group* or system running north-north-west to south-south-east belong a small number of dykes. The most important of these is a very large dyke, which for a large part of its course forms a low but very conspicuous rocky ridge, called the Karra Maldi (Curra Maldy), six miles west of Tawurugiri.

A *fourth group* includes a number of dykes whose course is north-west-by-north. The two principal members of this group are a large dyke which runs through the village of Bhagalwada, west of Bhanur (Bhunnoor) in the Raichur Taluq, and another large dyke which disappears under the Kaládgi basin at Rámapur, and apparently re-appears from below the Kaládgi rocks at Chimalga (Cheemulga), on the north bank of the Krishna.

4th Group: N. W. by N. to S. E. by S.

A *fifth group* may be established of dykes having a north-east to south-west course. A numerous set of these cross the remarkable inlier of gneiss in the Katharigarh hills in Belgaum district. Dykes pursuing this course are not numerous in the main gneissic area. There the largest and most important of this group is a very broad dyke, rising from under the regur three miles west-north-west of Beür (Behwoor), and running for about eight miles, till it joins another very large dyke with an east-by-south to west-by-north course, on the north side of which it does not re-appear or is lost immediately under the alluvium of the Krishna close to the village of Mudukop (Moodookop).

5th Group: N. E. to S. W.

There remains lastly to be noted a very remarkable set of dykes of great size and length, different parts of the course of which might be reckoned to belong to different groups. The main dyke is first seen at Togulugallu, a couple of miles south of Baman-Kallur, on the Raichur—Ling Sugur road. It forms a high rocky ridge, the Arrankerri hill of the map (north-west ¼ sheet 58) six miles east-by-south of Mudgal, and continues as a great north-east south-west dyke, rising at various places into rocky ridges, till about a mile west of the Ling Sugur—Bellary road, when it disappears suddenly. A branch of it given-off to the east of the road continues the same course for a while, and crosses the great Hunugunda schistose gneiss band about four miles north-east of Tawurugiri. It here rapidly trends in its course to the westward, and is joined by another large dyke about 600 yards

Jamalapur dyke group.

to the northward, which runs parallel with it for many miles. Just before the parallel dykes cross the Karra Gudda, a bold and very precipitous mass of naked black rock some 80 to 100 feet high, they are joined by the great Karra Maldi (Curra Muldy) dyke, and between them cover so large an area with huge blocks of black basaltic diorite that it would be very easy on cursory inspection to imagine one was dealing with a trap-flow instead of only a meeting of dykes. The parallel dykes are lost under a great cotton soil spread in the valley west of the Karra Gudda, and when they re-appear have trended to a west-by-north course, which they keep for a while, but continue trending till they reach a west-north-west course, which they continue till lost to sight a mile on to north-west of the Hanam Sagur head-land. The whole course of this set of dykes measures fifty-one miles, of which twenty-four miles are double and a few miles triple. Numerous dykes join, and several important dykes cross the set, but without showing any indications of belonging to different periods. The main line of this series passes near none but small villages. Jumalapur, which it is called after, is the most important and close to the central triple part.

Intrusive mass at Asmatti.

One more occurrence of dioritic trap deserves mention; it is that of a band of such width that it can hardly be reckoned a dyke, but unfortunately it is so completely surrounded by a vast unbroken spread of cotton soil that its relation to the gneissic rocks could not be made out. This doubtful trappean intrusion occurs at the village of Asmatti, five miles west-north-west of Nargund, and forms a long low rocky hill on which the village stands. To the north and south the ridge dies away rapidly under the cotton soil, but groups of large masses protrude at intervals, showing that it extends in a north-by-west to south-by-east direction for about three miles, with a width of two-thirds to three-quarters of a mile,—a width greatly exceeding the very largest of the ordinary dykes met with elsewhere in the Peninsula, the width of which was not more than 400 yards. For this reason, and from a slight difference

in the arrangement and aspect of the surface, I am inclined to regard this Asmatti trap ridge as either a contemporary flow lying in the general strike of the bedding of the gneissic rocks of this quarter; or else as a simply intrusive mass whose major axis is parallel with the general lie of the bedding. Excepting its excessive width, this mass of trap shows no peculiarity of mineral character of sufficient moment to render it distinguishable on lithological grounds.

As before mentioned, very few of the numerous trap dykes mapped during the progress of the survey demand separate notice on account of lithological peculiarities. The most noteworthy is a dyke of moderate size close to the village of Arranalli (? Urranulli), about twelve miles north-west of the great Madras Railway bridge over the Tungabhadra at Kachapur. This dyke, although belonging, as regards direction, to the "Doáb" group, differs from the other members of the group in being of a very pale diorite instead of the usual dark-blue or greenish-black color; but a yet more noteworthy feature is that it forms a kind of breccia by inclosing numerous large and small fragments of the blotchy hornblendic granite gneiss it has burst up through. The included fragments are of all sizes and shapes; many are laminar, others rudely spheroidal, and others again are thick angular lumps. Many fragments appear to have had their edges slightly fused. The dyke is about two miles long, fully 60 feet wide, and runs strictly parallel with the great Gutt Bichal dyke at a distance of about two-thirds of a mile to the north.

Dioritic breccia.

A small dioritic dyke, which occurs two and a half miles north of Ling Sugur, is distinctly porphyritic in character. The matrix is pale grey, and encloses numerous crystals of black hornblende about the size of a peppercorn.

Porphyritic diorite.

Another variation from the ordinary mineral character of the "Doáb series" occurs in a dyke situated about six miles north-north-east of Ling Sugur. In this dyke the rock is almost as fine in texture as pitchstone, and very different,

Compact fine-grained variety.

therefore, from the strongly crystalline texture of the ordinary dioritic dykes. In color this Yerrudoni dyke is blackish-grey instead of black or dark-greenish black. The hardness and toughness of the trap of this dyke are very remarkable.

The fineness or coarseness of the texture of the trappean rocks is in proportion to their width,—the smaller the dyke, the finer the grain of the rock. One very perfect little dyke, about 18 inches, which runs for several

Legend of Perkitti Rajah.

hundred yards among the fine granite gneiss hills west of Bhanur (Bhunnoor)* in the Raichur Taluq, has been associated by the natives with a very interesting legend for which I am indebted to Peshkar Anna Rao, who pointed out the little dyke to me.†

* Bhanur, or Mannur as it is locally more often called, a small town, of great antiquity according to native tradition, lies twenty-three miles south-west of Raichur. The crossed swords drawn in the Atlas Sheet about five miles west-by-south of the town have reference to the action in which General Arthur Wellesley overtook and routed Dundia Wag, the Mahratta freebooter.

† The legend is that Perkitti Rajah, who ruled at Manevi (the ancient name of Bhunnoor) more than a thousand years since, had one day, while hunting, completely outstripped his followers and found himself close to a well, near which sat an old man. Not knowing the old man to be a Rishi of tremendous sanctity, who was then and there engaged in practising further austerities and sitting in a state of complete mental absorption, the Rajah, who was desperately thirsty and tired, called out to him to bring him some water from the well. The old man stared at him and took no notice of his call, at which the Rajah became very wroth, but finding his request unattended to, had to dismount and go to the well himself. Having quenched his thirst he noticed before remounting that the body of a dead snake lay on the ground close by, when the idea came into his mind to hang it round the old man's neck in revenge for his incivility to a great Rajah. This he did and rode off home. Some time after the Rishi's son-in-law came up and was offended beyond measure on perceiving the gross insult which had been offered to so holy a saint. He roused the Rishi from his absorption, drew his attention to the insult he had been subjected to, and enquired who had passed that way. The Rishi replied nobody but the Rajah of Manevi, and thereupon in "holy anger and pious grief" proceeded to pronounce a tremendous curse upon him to the effect that he should be bitten by a snake and die within seven days. The Rajah when he heard of the curse got terribly frightened, knowing the relentless nature of the Rishi whom in his ignorance he had unfortunately insulted so grossly. To save his life, his people, by whom he was much beloved, immediately built a small tower of great strength, and with only one opening, on the highest and almost inaccessible peak west of the town,

2. Granite and Syenite veins and intrusions.

These form a very unimportant section in comparison with the great area of crystalline rocks treated of in this report. Though locally numerous in various parts, they are, as a rule, of very small size, and it is only in a few places that they materially affect the aspect of the general surface. They are most numerously met with in the valley of the Krishna, at and around Nalutwar, and westward nearly up to the Tungurgi ford over the river. None attain to large size, and many are very ill defined, of very variable width, and often appear to graduate into the surrounding granite gneiss. The granite is to ordinary inspection a binary compound of quartz and pink or red felspar (peach blossom to salmon color) and very coarsely crystalline. The great number of

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and thither Perkitti Rajah withdrew himself, hoping to tide over the fatal seven days. He had, however, taken the precaution to send for a famous Hakim, a great wizard, able by magic to cure any and every snake-bite, promising him an immense sum in gold if he would come in time.

In the meanwhile, moved by the Rishi's curse, one of the gods commanded Takshik, a prodigious cobra, that lived on the Adoni hills, to carry out the death sentence on the hapless Rajah. Takshik accordingly proceeded towards Manevi, and on his way thither fell in with the Hakim who was also proceeding thither in compliance with the Rajah's urgent summons. Rearing himself up on his tail, Takshik entered into conversation with the Hakim and enquired whither he was travelling. The Hakim, fond of a gossip, told the cobra the errand on which he was bound, and mentioned the enormous reward he expected to reap if he saved the Rajah's life. The wily Takshik immediately offered him a yet larger sum there on the spot if he would return the way he had come and leave the Rajah to his fate. The Hakim jumped at the offer greedily, and Takshik forthwith spun round on his tail, and, turning his back on the Hakim, muttered some great mantram, which immediately produced the required gold in a heap before the wizard's eyes. The Hakim took the gold and started homeward, leaving Takshik to proceed on his journey to Manevi. As he approached the Rajah's retreat, he was met by the Rajah's faithful pet mongoose, which vainly endeavoured to stop him, his little mouth being too small to get hold of the huge cobra. Scorning so impotent an enemy, Takshik pushed on up the bare rocky hill, staining the rocks in his course black with the saliva which flowed from his jaws, and, evading the numerous guards by some untold act of cunning, he entered the tower and gave Perkitti Rajah the fatal bite. The black stains caused by the saliva of the terrible Takshik remain to this day in the shape of the little dyke which runs up the face of the highest hill which itself bears Perkitti Rajah's name, while on and beside the dyke various little pittings of the surface are shown as the footsteps of the faithful mongoose.

these veins, specially near Nalutwar, their small size, very few attaining a width of four feet or over, and the irregularity of their course, rendered it impossible to map them. In some of the veins two varieties of felspar, apparently orthoclase, are seen: one peach-blossom colored and, enclosed in it, crystals or crystalline aggregations of a dark salmon-colored variety. These veins run in many different directions; but no difference in mineral character appears to mark the direction of the courses of the veins.

Granite veins showing lode-like structure.

Of individual granite veins the most curious and interesting is unquestionably one occurring at the village of Madinhal in the Muddibehál Taluq (Kaládgi district), and about 4 miles west-by-north of the taluq town itself. This granite vein shows in its structure close affinity to many metalliferous veins or lodes. It shows nine or ten separate bands of color, white and red; the white bands being mainly made up of quartz, and the red ones of dark-red felspar, with many quartz crystals.

A few small acicular crystals of hornblende, or tourmaline (?), occur in the mass, but were too much weathered to be identified. The vein traverses a mass of grey hornblendic granite-gneiss, on which stands part of the village wall. The bands of color must have been formed either by successive processes of infiltration or by segregation out of a fluid magma.

A small intrusive mass of syenite, of coarse texture and dirty green color, occurs about 2½ miles north-west of the above-mentioned vein. Its relation to the adjoining rocks was obscured by soil.

Granitic veins of various characters are mentioned in Mr. King's notes as occurring in different places in the Raichur country, *e. g.*, at Yerrugerri, where veins of red felspathic granite with chlorite are seen traversing well-bedded gneiss. Again, at the village of Tontapur (Toontapoor) red felspathic granite with chlorite and a few garnets is found traversing dark-grey and the ordinary grey granite gneiss.

Mr. King also mentions the occurrence of coarsely crystallized quartzo-felspathic granite in granitoid gneiss at Turkandona*: "half a mile north of the village there is a good spread of the same granite showing the white felspar crystallized, so that it gives quite a brilliant pearly-glassy lustre to the rock in a cross light. There is a little brown mica in this granite."

The granitoid gneiss is in many places much cut up by small granitic veins, which frequently cross each other variously, and often give rise to very strange and grotesque shapes in weathered blocks. These are frequently collected by the natives and stuck up in fields or under trees, to do duty as idols, especially in place of the "ling" or phallic emblem. Some are even promoted to do duty in front of the village temples. One such I sketched in the village of Arehshankar in front of the principal shrine, where it served as a figure of Nandi, Shiva's sacred bull. I examined it very carefully, and could not find the slighest indication of human workmanship on it. The side view only presented the likeness to the recumbent bull; seen from before or behind, the stone looked merely like a rude slab with its upper edges much rounded by weathering. The strange shape is mainly due to the position and greater durability of the three small granite veins included in the mass, two of which made the head and face, and the third the flat base on which it stands.

The most important intrusive mass occurring in the Konkan gneiss area is that forming the high and conspicuous Waraora hills (Wagheree station of map), five miles east-by-north of Vingorla. Mr. Wilkinson describes the main mass of these hills as composed of porphyritic syenite and hornblende rock. "The Waraora hills are more than twice the height of the laterite ones, and they present a striking contrast to these, being irregular in shape, conical, and thickly wooded, whilst the laterite hills are nearly flat-topped and almost devoid of vegetation."

* About 8 miles to the north-north-east of the great railway bridge over the Tungabhadra at Kachapur.

3. Quartz reefs and veins.

Not many examples of this form of rock were met with, but several of them were of considerable size and importance. They consist mostly of pure white quartz, showing, in some cases, an obscure, quasi-brecciated structure, which is most conspicuous where the apparently included fragments are surrounded by a pale green chloritic staining. This staining is, generally, only locally seen. It may be well developed in a small part of a reef and not at all seen in other parts. A good example of such a quasi-brecciated reef is that running north-westward from near Nykal on the right bank of the Bhima, and forming a ridge whose northern end is locally called the Murubukul. In a small quartz reef, a mile and a half north-west of Bhanur (Bunnoor) in the Raichur Doáb, the chloritic surrounding of the quasi-breccia fragments amounts to a distinct film.

The large quartz reef at Bahadurdinni, six miles east of Kautala (Civital), is also a good specimen of the quasi-brecciated quartz.

Some of the reefs present a laminated structure, closely resembling true bedding. A remarkable instance of this may be seen in the large reef at Marudgi, on the left bank of the northern branch of the Krishna, 3 miles north of the junction of the Ghatprábha with the southern branch. The reef here appears to have a dip of from 70° to 85° south-by-east, and the lamination is very distinct in the middle part of its course, owing to the presence of thin films of hæmatite between many of the laminæ.

Although, generally, these reefs consist of pure quartz only, with but few important enclosures, there are some cases in which they show a large amount of some accessory mineral, specially of the specular variety of red hæmatite. The most noteworthy example of this occurs in the double reef at Yerramarsu (Yerrumursoo), 2 miles north of Siriwar (Seerewar), a large village on the Raichur—Ling Sugur road, and about 21 miles west of the former place. The ore occurs in numerous little

veins, which are so disposed as to give the quartz a very strongly brecciated appearance in parts. Another reef, containing specular iron, but in much smaller quantity, occurs at Sultanpur, 2 miles south-east of Govur (Goboor) in the Raichur Taluq. At the southern end of the hills, occurring in the Maski (Mooski) schistose band, and about 6 miles north of that place, is a small quartz reef which runs due north and south, and has been mined by the natives for some mineral or other, but what I could not ascertain either by inspection of the reef or by enquiry of the people, who said the inclined passage, which penetrates some 30 or 40 feet, was of such great antiquity that nothing was known of its origin. The bottom of the passage was full of water and was said to form a perennial stream. The place would seem to be held sacred (or uncanny ?), for the people seemed annoyed at my having been there, and most unwilling to answer my inquiries regarding it.

The only minerals I could find in the quartz were small strings and coatings of earthy limonite, and a yellowish grey sparry mineral, like spathic iron, but hardly affected by acids. This mineral occurred in small quantity in nodular and stringy masses. There were no indications of any sulphides.

The great quartz reef forming the Mallapur Trigonometrical Station hill, a very conspicuous red ridge 8 miles north-north-west of Raichur, is described by Mr. King as a fault-rock, a brecciated dark-red, brown, and yellow jaspideous rock, much stringed with white quartz. It appears to be bedded, and to have a low dip to the north-west, while the strike is about north-east. The rock is much fissured or jointed, the joints being vertical or having a dip of 70° to 80° south-east. No traces of any iron ore were seen, except the occasional ferruginous staining already adverted to. A large and conspicuous reef was mapped by Mr. King near Urkaree (Urkera), about 8 miles north-west of Yadgir (Yeedageery). This reef, which crosses the Great Indian Peninsula Railway at Kanhalli, is really a triple one, measuring altogether about

200 yards across. The rock is amorphous, dull white quartz, slightly ferruginous in parts, and much split up by joints and other fissures.

Other reefs occur scattered about the gneiss area with which the report deals, but they do not merit special enumeration.

Quartz veins.—This heading includes the smaller and less well-defined quartz runs, of which the number is simply legion. As a rule, with very few exceptions, they are of very small size and extent and run in all possible directions. They are also often very ill defined. In none were any traces of sulphides observed, not even in those seen in the auriferous tract in the upper valley of the Malprábha.

CHAPTER IV.

THE KALÁDGI SERIES.

A GREAT series of rocks, in many respects closely resembling the Kadapah series, forms a well-marked basin, lying mainly between the banks of the Krishna and the Malprábha rivers.

In geological sequence these rocks occupy the second rank, being the next in age to the gneissic series, on which they rest directly and unconformably.

The Kaládgi basin.

The shape of the Kaládgi basin is so irregular that it will be far better understood by a glance at the accompanying map than by any verbal description. Beyond the boundaries of the Kaládgi basin proper are numerous outliers resting on the older rocks, and inliers exposed by denudation within the area of younger rock series.

Outliers and inliers.

The principal of these are on the western side of the basin: the Mangaon inlier in the upper valley of the Harankashi river, the Shengaon and Assungaon inliers in the valleys of the Ved Ganga and Dudh Ganga respectively, and the Lora inlíer in the Konkan at the foot of the Phonda Ghát.

There are a number of smaller inliers among the Deccan trap to the north of the Lora inlier, and several small ones among the laterite plateaux, near the coast, northward of Vingorla, and one small outlier, far removed from the others, rests cn the gneiss some miles south-west of the Ram Ghát. On the north side of the basin are the Jamkhandi and Galgali inliers, on the south bank of the Krishna; a string of tiny inliers among the trap stretching from Mahalingpur to Serul, and a group of large and small ones on the south bank of the Ghatprábha near Yadwad. North of the Krishna, at and near Mamdápur in Bijapur Taluqa, are two small exposures of the Kaládgi rocks, which are partly

inliers, partly outliers, as they both overlie small patches of gneiss and are themselves overlaid by the Deccan trap on three sides. To the south-east of the Kaládgi basin are the Gudur and Hanamságar outliers and a group of outliers between Belur and Gajendragarh. Finally, to the south of the basin are the outliers capping two hills of Nargúnd and Chik Nargund, and that capping the Parasgarh hill and two small ones to the north-east of it.

By far the most important sections are, however, found within the boundaries of the Kaládgi basin itself, which will therefore be most fully described.

Taking the series as a whole, it is decidedly metamorphic where disturbed. The disturbed parts are those lying within the basin; the undisturbed with a few exceptions are the outliers at the eastern and western ends of the basin. Not the faintest trace of any organism rewarded much earnest and close search, and as previous explorers had been equally unsuccessful, the Kaládgi series may for the present be regarded as azoic.

The whole series may, after careful examination, be sub-divided as follows in descending order:—

	Estimated thickness.	
B.—Upper Kaládgi Series.		
6. Shales, limestones, and hæmatite schists ...	2,000,	?
5. Quartzites, with local conglomerates and breccias	1,200,	1,800,
A.—Lower Kaládgi Series.		
4. Limestones clays, and shales, ...	5,000,	6,000,
3. Sandstones and shales	} 3,000,	5,000,
2. Silicious limestones, hornstone or cherty breccias		
1. Quartzites, conglomerates, and sandstones ...		

Thickness.

The aggregate thickness of the whole series has not been satisfactorily determined, as no sections were found in which both top and bottom of the two limestone and shale series were exposed; only imperfect estimates of their thickness were possible; but even these show that the series is of very great thick-

ness, probably not less than from 10,000 to 15,000 feet in the region south, north, and north-east of Kaládgi.

The thickness of the quartzites and sandstones in the gháts belonging, apparently, to the lower series, cannot be less than 1,000 feet, as seen in the spurs and outlying hills near the base of the Phonda Ghát section, and is probably very much greater.

Geological position of different sub-divisions.

The members of the upper division are confined to several small areas, all lying within the Kaládgi basin and clustered round that place itself; and the limestones and shales belonging to the upper section of the lower division are almost entirely confined to the eastern half of the basin. No limestones, and hardly any shales, were seen westward of 75° E. longitude, all the beds westward of that meridian belonging, to all appearance, to the lowest section (1) of the Lower Kaládgi series.

Illustrative sections.

The following six sections given on Plate VIII illustrate the relative positions of the two divisions of the Kaládgi series and the underlying gneissic and overlying trappean rocks.

The sections follow each other in an east-to-west succession:—

1. From the Krishna to the Shiakeri ridge south of Bagalkot.
2. From the Krishna to Kaládgi.
3. From the Krishna to Manekeri ridge, near Hulkund.
4. From the fall of the Ghatprábha at Gokak to Melmihatti.
5. From Manekeri ridge to Sogal.
6. From the Phonda Ghát to the sea, near Malwan.

Their teaching.

The sections are diagrammatic in part, and the vertical scale is arbitrary. They show all the principal disturbances the series has undergone, all of which took place long prior to the deposition of the Deccan trap-flows. Another important feature, which becomes obvious from a study of these sections, is the enormous amount of denudation which has affected the country since the conclusion of the Deccan Trap period. That an immense

period elapsed between the upheaving and contortions of the Kaládgi series, and the outpouring of the Deccan trap-flows, would be abundantly clear from a consideration of the vast amount of denudation the older set of rocks had undergone, even if no other evidence existed to indicate how vast an interval of time had elapsed.

A.—Lower Kaládgi Series.

The base of the Kaládgi series, wherever seen, reposes on the gneissic rocks, the surface of which was in some parts very uneven, so that the basement beds of the younger groups of rocks may in some places be seen to lap round prominences rising from the surface of the older rocks.

The silicious members of the Lower Kaládgi rocks seem to be made up entirely of materials derived from the degradation of the gneiss series, and in many beds of the former it is quite possible to distinguish from what members of the gneissic series the constituent materials were derived.

This lower series has been sub-divided into two principal sections in accordance with the natural petrological sequence observed, and the lower of the two sections is again divisible into three sub-sections. They are as follows:—

II.	4. Limestones, clays, and shales.
I.	3. Sandstones and shales.
	2. Silicious limestones and hornstone breccias.
	1. Quartzites, conglomerates, and sandstones.

The three lower sub-divisions are, however, so intimately connected in the field that it will be advantageous to consider them together in the same section.

I.—*The Lower Kaládgi quartzites conglomerates, breccias, and sandstones.*

The basement beds of the Lower Kaládgi series, which constitute sub-section No. 1, consist of conglomerates, grits, sandstones, and quartzites of great thickness in the aggregate. These form the bulk of the rocks

belonging to section I; but occasionally beds of shale or shaley flags are met with, and in one place several beds of hæmatite-schists are intercalated among the quartzites. The members of this sub-section occupy the whole of the western part of the Kaládgi basin and the greater part of the southern area, while on the eastern and northern sides of the basin they form a broad border round the central part of the basin occupied by the overlying limestones and shales. This border is continuous except where overlying trap-flows conceal it. All the outliers east, south, and west of the basin, and all the large and important ones north of the basin, were once part of the basement section of the series.

As might be expected of a rock series extending over so large an area and formed of materials derived from an older series, the members of which are so diverse in character, there is a great deal of local diversity of texture and color, the relative characters of the more important sub-divisions are to a great extent constant, and the gradual decrease in coarseness of texture from below upwards holds good almost everywhere.

Resting upon the basement beds are found, in eastern and southern parts of the basin, beds of intensely silicious limestone, which in many places pass (or at least appear to pass) into very characteristic hornstone or chert breccias. Resting upon these come, in most parts of the basin, the clays, shales, and limestones grouped together in sub-section No. 4. Locally, however, in the southern and the western parts of the basin, an important group of sandstones and shales appears to be intercalated between the breccia beds and the base of sub-section 4. Unfortunately the great imperfectness of the local sections, and the intervening of a broad band of the Deccan trap, combine to make the relations of all these beds extremely obscure and rather doubtful.

Basement beds almost upturned.

The rocks forming this section as a rule lie rather upturned, the outer boundary scarps forming a true basement edge. Such is the case round the greater part of the Kaládgi basin. Within the area of the basin they are usually undulated, but are in some places met with lying horizontally and in others have been considerably disturbed and crumpled.

Locally undisturbed.

In those parts of the basin which lie east of the Malprábha river round Gudur and in the outliers to the south and east, the conglomerates and sandstones appear to be almost entirely undisturbed, and to be occupying their original positions of deposition, and in them a minimum of metamorphic action is found to have taken place. Nearly the same may be said of the greater mass of the beds in the western part of the basin and in the outlying areas occurring in the different valleys on the ghâts.

Colors of the rocks.

In the conglomerates and lower-lying grits the color of the rock varies much more than in the higher-lying beds, and is seldom continuous for more than a few miles,—indeed, often changes rapidly within short distances. Among the conglomerates shades of purplish grey and dark-purple are very common; pinkish-grey is also common from the presence of large quantities of pink felspar, derived from the decomposed granite-gneiss rocks; whitish grey where quartz pebbles abound, and light reddish-brown as a general color, are also of very common occurrence. The shaley beds are mostly without any very remarkable colors; usually they are drab or pale ashy grey.

Jasper conglomerates.

In the neighbourhood of the jaspery hæmatite-schists of the gneiss, the conglomerates are in many places almost entirely composed of rolled or angular fragments of the jaspery hæmatite of all colors peculiar to those remarkable beds.

The cherty breccia beds are peculiar features of the Kaládgi basin, and help greatly, by their peculiar mode of weathering into disconnected fragmentary masses with much small debris, to obscure the relations of the under and overlying rocks. From their position and from their relations to the great bands of very silicious limestone, highly charged with bands and segregations of silica in the form of chert, which occur in the southern part of the Kaládgi basin to the north and north-west of Manoli, there seems good reason to regard the breccias as altered portions

of such highly silicious limestones. The change into the breccia condition was probably caused by the percolation of highly acidulated waters which removed so much calcareous matter that the cherty skeleton remaining was broken down and comminuted by the weight of the superincumbent mass of rocks. Subsequent infiltration of silicious, calcareous, and argillo-ferruginous matter formed the comminuted chert into a breccia with variable cement.

There is no evidence as to the period when this change took place, but it is quite probable that the great part of the change may have been effected during the period of volcanic activity which produced the Deccan trap, during which much evolution of acid vapours may have acidulated the water of all that region.

Best scenery all connected with the lower quartzites.

It is to the prominence of this section of the Kaládgi series, or to the action of erosion on the great thickness of silicious rocks composing it, that the diversity of outline, and what little beauty of scenery is to be seen in the South Mahratta country outside the Ghát region, is attributable. There are not very many spots in the South Mahratta country east of the Gháts that afford much pleasure to the lover of the picturesque in nature; and in most places man's hand, by ruthlessly and, as the result shows, foolishly destroying everything worth calling forest, has rendered the scenery far less pleasing than it would otherwise have been. The prettiest parts of the country are the valleys of the several rivers where they cut through the various low hill ranges, as the valley of the Malprábha at Ramdhal and from Aiholi (Iewullee) to Nandi Késur (Nundeekasur) in the lower parts of the river. In the middle parts of the valley, Sulah, Ramdurg, Torgal, and Basargi (Bussurgee) are worth seeing; while, last of all, the deep gorge known as the Naul Tirth or "Peacock's bath" is one of only four spots within the Kaládgi basin which I would call beautiful, the other three being the falls of the Ghatprábha at Gokák, the gorge of the Márkándeya river also close to Gokák; and lastly,

Bádámi with its cliffs crowned by two hill forts and the valley between them. The upper part of the Malprábha valley above the gorge is quite tame till close to Khánápore, where the Ghát region may be said to begin. The scarp of the quartzites forming the basset edge of the Kaládgi basin shows fine bold mural cliffs in various places as at Sogal, Murgod, Sidapur, Wannur, and Hoskatti. The curious Kathárigarh (Kuttargurh) valley would be very picturesque if well wooded. At Sogal there are some very pretty waterfalls, the largest of which is over a fine cliff of quartzite conglomerate. The place is held sacred, and some good trees have been allowed to remain round the pagoda on the top of the cliff. The Gatprábha valley has even less to show below Gokák; there is hardly anything to arrest the eye till between Bagalkot and Yerkal, where the river twice breaks through the upturned edge of the quartzite series, backed up at the latter place by a fine outcrop of hæmatite schists of gneissic age, and leaves and re-enters the Kaládgi basin. The valley of the Krishna is rather pretty at Galgali (Gulgullee), and again at Sitamani (Seetamuna), where it breaks through a barrier of quartzites and conglomerates forming the north-eastern extremity of the Kaládgi basin. Outside the limits of the basin, the hill forts of Parasgarh, Nargund, and Gadjendragarh are worth seeing, and north-west of the last-named place some fine bold rock scenery is to be seen in the valley running from Murudi down to Gudur, and thence to the Malprábha, and also the valley running north from Niluwagal till it joins the former. The old ruined hill fort of Wokund, two miles west of Niluwagal, which stands perched upon a bluff mass of sandstones, is also a picturesque spot. These places are enumerated because the South Mahratta country, and the Kaládgi district more especially, has the reputation of being more ugly and uninteresting than it really is. The scenery presented by the rocks belonging to this section within the Ghát region is less varied and less picturesque than might be expected, certainly less so than that of the trap hills which surround them. The barren sandy soil they weather into bears but a scanty growth of forest trees, even where it has not been artificially spoilt by

Quartzites support little vegetation.

jungle fires and wood-cutters. This character of poverty in vegetation belongs to the quartzites and sandstones almost universally.

Series of sections round the Kaládgi basin.

The following series of sections will show the characters of the different members of this sub-division of the Kaládgi series in sufficient detail to admit of a correct idea of their general nature being formed. The series begins at the extreme eastern end of the Kaládgi basin and follows the boundary of the basin northward and westward, crossing and re-crossing the Krishna to Galgali (Gulgullee) on the south bank of that river. From these the series of sections extends into the great inlier which forms the Jamkandhi ridge, stretching from opposite Biddree on the Krishna to Turdul (Tardal). Hence the series of sections extends to Gokák and along the Gatprábha valley to beyond Neseri (Naiseree) in the southern part of Kolhapur State, from where it follows the line of great and small inliers which connect, or rather indicate, the continuity which subsisted before the trap covered up the surface of the country between the Kaládgi basin and the homologous rocks in the Southern Konkan, at the foot of the Phonda Ghát. The series is then taken up again close to Kákti (five miles north of Belgaum) and followed along the southern and south-eastern boundaries of the Kaládgi basin to the gorge of the Malprábha at Rámdhal, which completes the circuit. There are many equally good sections at spots intermediate between those given; indeed, the ridges formed by these basement beds have been so extremely denuded of jungle that they are very bare of soil. The only hindrance to ascertaining the exact nature of the rock is in most cases merely the immense accumulation of debris on the surface of the beds or on the slopes of the hills.

Sections on the north-east and north sides of the Kaládgi basin.

a.—Amingarh (*Ameengurh*) *Section.* The narrow spur of Kaládgi rocks which crosses the Malprábha at Kamatgi (Kummutgee) forms a synclinal valley which terminates in an elliptical curve to the westward of the ruins of the old Amingarh (Ameengurh) fort. The succession

of beds here seen (which all belong to the lowest section of the lower division of the Kalâdgi beds) is as follows in descending order :—

c. *Upper breccia,* "chocolate" breccia.

b^1. *Quartzites,* brown and red-brown, gritty.

b. *Chocolate or dirty breccia,* the matrix locally very rich in hæmatite.

a. *Quartzites,* brown *gneiss,* drab and salmon-colored, gritty.

The base rests partly on schistose hæmatite and talcose gneiss, partly on hæmatite schists. The surface of the brown gritty quartzite bed "b^1" has been weathered in parts into great pinnacled tors unlike anything met with elsewhere among the Kalâdgi rocks.

b.—Khirsur hill Section. The section in the Khirsur hill, one of the highest hills in the Bagalkot Taluq and lying three miles east of the town, shows the following beds :—

c. *Breccia bed.* " Dirty breccia."

b. *Quartzites,* a thick series, grey, pink, and drab.

a. *Conglomerates* forming the north scarp of the hill.

Gneiss.

c.—Adumurunhal Section. In the Adumurunhal (Adoomoorunhal) section, in the gorge of the Ghatprâbha river, north of Bagalkot the beds exposed are :—

c. *Breccia,* with ferrugino-calcareous cement.

b. *Quartzites,* whitish, pale-red, brown, &c., &c.

a. *Conglomerates,* coarse and fine, with some intercalated beds of quartzite.

Gneiss (chlorite schists, &c.).

The conglomerates in the section are very remarkable for their great beauty of color. The matrix is generally a purple or purplish grey, gritty quartzite of great density, including numerous pebbles of jasper

and hæmatite schist, derived from the beds of those rocks in the gneissic series. The pebbles are all well rounded and so firmly impacted that in most cases they have split in two where the rock has got fissured. Along the summit of the ridge, a little west of Adumurunhal, the display of jasper pebbles, many of them of vivid red color, is such as to remind one of a bed of bright red tulips without any green foliage. In many parts where the rock has been freshly fractured by weathering and still retains its semivitreous lustre the effect is really fine, especially when lit up by the midday sun.

d.—Tumurmatti (*Toomoormuttee*) *Section.* At the apex of the sharp horse-shoe curve the basement series makes between the two gorges of the Ghatprábha at Adumurunhal and Yerkal, another capital section is to be seen which reveals the same succession of beds as in the foregoing, namely,—

c. *Breccia bed,* greatly broken up and weathered.
b. *Quartzites,* drab, buff and reddish.
a. *Conglomerates,* purple with jaspery hæmatite schist pebbles.
Gneissic series, here consisting of hæmatite schist and chloritic schists.

In this case some of the conglomerates approach more to breccias from the imperfect roundness of the contained fragments of the older rocks, many of which are sharp splinters. The matrix of the conglomerate is richly ferruginous, consisting largely of comminuted hæmatite joined by a ferruginous cement. The included pebbles are generally much smaller than those seen on the ridge west of Adumurunhal referred to above.

e.—Yerkal Section. The Ghatprábha river breaks through the boundary ridge for a second time and re-enters the Kaládgi basin at Yerkal (or Herkal) three miles north-north-west of the first or Adumurunhal gorge, and forms a gorge having a strong claim to be considered

as a really picturesque spot in a very generally tame, if not positively ugly country. The section of the basement series here displayed is one of the most clear and instructive to be seen in this region. Little or no detritus obscures the several rock-beds here exposed which occur in the following succession :—

c. Breccia, calcareo-ferruginous or "dirty breccia."

b. Quartzites, buff, pink, and brown, with intercalated shaley sandstones.

a. Conglomerates and quartzites, the former purple, the latter purple and grey.

Gneissic series. Highly contorted beds of jaspery hæmatite schists.

Some of the beds of quartzite include thin layers of pebbles. Many of the pebbles and fragments in the conglomerates consist of jasper and jaspery hæmatite. The hæmatite beds form the very fine cliff shown in Plate III. The conglomerate beds are lying against the north wall of the hæmatite cliff. The rocks in the middle of the river are part of the lowest conglomerate bed and dip north or away from the spectator. The low and rather shelving cliff on the right or east bank of the river is part of another hæmatite schist-bed running parallel to the north of the main ones. The low rising ground behind the great tope consists of limestones and shales and the breccia bed "*c*" which underlies them; and all are faulted against the gneiss along the northern boundary of this part of the basin immediately behind the rise.

f. Sitamani Section.—This section, like the last, is very clear and instructive, the various rocks here making up the basement series being well exposed on the Sitamani (Seetamunna) hill on the south side of the gorge through which the Krishna here forces its way across the north-east extension of the Kaládgi basin. The boundary ridge of the

basin has been but imperfectly broken through, and forms a great barrier reef across the river bed. The succession of beds here seen is the following:—

c. Breccia beds; a jaspery variety of the "dirty breccia."

b. Quartzites; grey and salmon-red.

a. Conglomerates and grits.

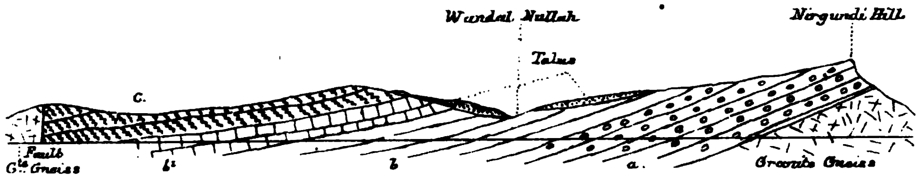
Granitoid gneiss.

The grit beds are generally of coarse texture; like the conglomerates, they consist of white and greyish-white quartz pebbles and red felspar debris. The matrix in both is purplish or grey in color.

At Rámápur, a mile and a half south of the Sitamani gorge, the section differs considerably from the foregoing; the conglomerates, which are of great thickness at Sitamani, being absent. The basement beds are grits of no great thickness, overlaid by quartzites of salmon, red, and purple-brown colors, which are greatly rippled in parts. The gritty beds rest on granitoid gneiss, traversed by numerous dykes of dioritic trap, both large and small in size, but all older than the Kaládgi rocks.

g. Nirgundi Hill Section.—From the extreme north-east point of the Kaládgi basin at Nirgundi (Neergoondee) westward for a distance of seventeen or eighteen miles the northern boundary of the basin is formed by a fault by which the rocks forming the basement series are thrown down and abut against the gneiss. All the Kaládgi rocks which once lay upon the gneiss northward of the line of fault have been denuded away. There is no section in which the dislocation of the rocks is actually visible, but the sketch section below demonstrates clearly that a very considerable dislocation exists. The succession of rocks seen in the corner of the basin north of the Krishna differs

somewhat from that in the other sections already given by the appearance of a thick bed of limestone between the quartzites and the breccia beds.



Sketch Section across Nirgundi Hill.

The succession of beds is as follows :—

c. *Breccia of chert or hornstone ;* brown, red, and bluish grey.

b^1. *Limestone* with cherty bands; grey and reddish grey.

b. *Quartzite sandstones ;* shades of brown.

a. *Conglomerates and pebble beds ;* pink, brown, and grey.

Gneiss.

Small patches of dark iron-clay, most probably of subaerial origin, occur dotted about on all the different formations. The limestone bed is hidden by debris along the line of section, but shows at some distance on either side. Here, as at Sitamani and Ramapur, the included pebbles are mainly quartz and felspar in a sandstone matrix.

k. Bilgi Section.—The next section worthy of separate notice occurs a little south-west of Bilgi (Beelgee), twenty miles further west. The succession of rocks is here normal and the beds seen are—

c. *Breccia bed ;* jaspery.

b. *Quartzites ;* drab and red, blue and grey, drab and pinkish.

a. *Grits and conglomerates.*

Granite gneiss.

The conglomerates are unusually thin here, and the quartzites proportionately thick. The quartzites are quarried, and a very remarkable monolith, a *stambha* or sacred lamp-post, standing on the top of Bilgi hill, is said to have been quarried here. This will be referred to again when treating of the economic geology of the South Mahratta country.

i. Bisnal Section.—The village of Bisnal lies eight miles west-by-north of Bilgi; the section was taken about half a mile south of the village in a south-east to north-west direction and shows the following succession of beds:—

c. Breccia beds; bands of earthy (ochrey) impure limestone at base.

b. { *Quartzites and shaley quartzites* of whitish color.
Quartzites, red and gritty. }

a. Grits and conglomerates; grey, or reddish, of quartz and felspar debris.

Granitoid gneiss, red.

In the corner made by the bend of the hills (due to the trending of the strike of the rocks) about a mile and a half south-by-east of the village are four beds of richly hæmatitic schist among the quartzites about the horizon occupied by the upper part of "*b*" in the foregoing section. They give rise to four distinct scarps, due to their greater resistance to atmospheric influences. A small quantity of ore was being collected there in 1871, to be smelted at the neighbouring villages of Sidapur (Seedapoor) and Jenmatti (Jehnumtee). As shown in the map, a line of fault, accompanied by a considerable downthrow on the north side, occurs at the village of Bisnal, the dirty breccia being faulted against underlying conglomerate beds. This fault and downthrow may be traced for several miles to the north-east crossing the Krishna to Jainapur (Jynapoor), and finally disappearing under the Deccan trap about two miles north-east-by-north of the latter village. At Jainapur

the quartzites are faulted against the gneiss, but the contact is hidden partly by an overlap of the Deccan trap, partly by thick cotton soil. There is a good show of red quartzites and "dirty breccia" in the bank and bed of the river. The breccia, which is very jaspideous in texture, forms a small island and several reefs in the river. The quartzites have a westerly dip of 45°.

Jainapur section.

About four miles to the north of the Jainapur ridge at Mamdapur, in Bijapur Taluq, are several exposures of the Kaládgi rocks which are partly inliers in the Deccan trap area, partly outliers resting on the gneissic series. There are seven of these exposures forming a row of small low hills, rising but little over the general surface of the Deccan trap, and running for six miles nearly due east to west with only one considerable break.

Mamdapur section.

Six miles west-south-west of Mamdapur is another small exposure of similar character at Kangalgutti (Kungulgoottee); all these consist of purplish grits and reddish quartzites with pink, chocolate, and drab-white micaceous shales, belonging to the basement beds. The usual conglomerate beds are absent.

Another interesting inlier of the lower beds, one of a group of three occurring at Galgali (Gulgulleh), is to be seen in the bed of the Krishna when the river is low. The beds of quartzite there form a low, flat, anticlinal ellipse (with dips varying from 3° to 7°) by which the river is dammed back to some extent, and a rapid formed near the northern bank. The rocks seen are grey quartzites and shaley beds overlaid by light-red rippled quartzites, much cut up by a most complex system of jointing. These are seen to be overlaid in the right bank of the river by impure grey limestone with bands of chert and also of impure red, yellow, or drab ochrey quartz, and some white chalk-like laminæ, the whole capped by dark-grey quartzite, on which rests the Deccan trap which forms low cliffs on either side of the river. The beds exposed in this section are of very small aggregate thickness.

Galgali inlier.

j. Mantur (Muntoor) Section.—About eight miles west of Bisnal, the following set of beds is exposed on the eastern part of the large inlier of quartzites, north of the village of Mantur, in the Mudhol State. The section, both ends of which are covered up by the surrounding Deccan trap, shows the following beds along the path leading to Konnur:—

Quartzite, reddish.
Clay rock, dull green-grey to grey.
Quartzite, reddish.

These beds probably belong to quite the upper part of the series. Part of the clay rock bed is banded with black, and, being rather calcareous and of good consistency, would make a very handsome building stone.

k. Jamkhandij Section.—In the section seen in the deep valley running south from the town of Jamkhandij, a great thickness of beds forming the lowest section of the Kaládgi series is seen, although both the uppermost and the basement members of this division are covered up by the trap.

The thickness of the series here exposed was found on rough measurement to exceed 2,500 feet. If the whole series were seen, it would very probably exceed 3,000 feet. The different beds seen are—

Deccan trap.
c. *Shaley sandstones*.
b. *Quartzites*, drab and salmon-colored.
a. *Grit beds*, of purple, purplish, reddish and pinkish-brown color, greatly false-bedded.
a. *Grit*, hard, red.

Some of the purple grits contain many angular fragments of pink and red felspar and have a remarkably porphyritoid appearance, in this respect closely resembling the arkose of continental geologists. The hard, red grit, bears a very strong resemblance to a granite-gneiss, and might very easily be mistaken for it.

J. Schaumburg Lith

FALL OF THE GHATPRABHA NEAR GOKAK.

1. Rabkavi Section.—In this section nothing but quartzites, with a few intercalated beds of drab or pale reddish-white shaley sandstone, are seen. The quartzites are of reddish-brown, pinkish, purplish, and greyish-drab colors, and, as in the Jamkhandi section, all the beds dip southward and are extremely regular in their succession and position. Both ends of the section are covered up by the Deccan trap. In both these sections the line of the valley along which the section was taken lies north and south.

2. *The Gokák Sections.*

The lower parts of the basement series are well displayed around the town of Gokák in Belgaum district.

The great series of pebbly and gritty quartzites which are here to be studied in numerous good sections show but little that deserves special notice, being remarkably uniform in their color and texture. Drab to reddish-brown are the predominant colors. The panoramic view of Gokák town and the hills behind it which forms the frontispiece shows how numerous are the lines of cliff in which the basement beds may be studied. The best section is that to be seen in the gorge of the Ghatprábha, just below the famous and beautiful fall the river makes in descending from the Ghât region into the Deccan proper. The total thickness of quartzites and conglomerates exposed cannot be much less (and probably is more) than 400 feet vertical, of which more than 300 feet is exposed in the cliff on the north side of the falls. The scenery of Gokák and its environs is very pretty and the place well worth visiting. It is moreover the best centre for geological studies in the whole South Mahratta country.

Falls of Gokák.

The Ghatprábha river has, as the accompanying sketch (Plate IV) shows, cut itself a horse-shoe shaped basin, into which it falls over a cliff 178 feet high,* and forms a deep pool of dark brownish-green water. The view is taken from the south edge of the gorge below the

* According to the measurements of Captain Newbold, F.R.S., &c., &c.

fall from a place almost exactly opposite the centre of the horse-shoe, which it rather overlooks, and whence decidedly the best general view is obtained. The beauty of the scene is much marred by the presence of an immense quantity of the common prickly pear, which has been allowed to run wild to a lamentable extent over the Gokák hill, as well as in other parts of the Belgaum district. It perfectly chokes all other jungle growth and is itself the most pestilent of weeds.

The curved lines showing the outcrops of the quartzite beds are very conspicuous on the face of the cliff. The curves must not, however, be taken to indicate correctly the form of the synclinal, for they are considerably exaggerated by the effects of perspective and of the peculiar amphitheatrical form of the face of the cliff. The narrow dark band near the foot of the cliff is really a recess in the rock due to the more rapid weathering away of a bed of shaley sandstone. It is of sufficient size to make a passage by which it is possible for people with steady heads to get behind the falling mass of water. Except in the rains but little water is seen in the rocky bed of the river above the fall, for it runs in narrow channels cut deep into the rock till just as it reaches the brink of the cliff, where it spreads. For some distance above the fall the water runs at a very great pace, and has in consequence worn many fine specimens of pot-holes in the very hard quartzite, some beds of which, both here and in many neighbouring sections, are typical "waxy" quartzites, showing beautifully preserved rippling. These pot-holes are very favorite bathing places for numerous Brahmins and others, who perform semi-religious picnics at this lovely spot in honor of Mahalingeshwar. The grandeur of the fall depends greatly on the volume of the river, which varies much according to the season. A graphic description of it when the river is full in the rainy season was given by the late Captain Newbold, F.R.S. (in his geological notes on the South Mahratta country). After adverting to "the magnificent spectacle of a mass of water containing upward of 16,000 cubic feet precipitated from the tabular surface of the sandstone into a gorge forming the head of the defile," he continues: "the

Ghatprábha, a little above the fall, is apparently about 250 yards across, but contracts to 80 as the brink of the chasm is approached; consequently the density and velocity of the watery mass is much increased, and it hurries down the shelving tables of rock with frightful rapidity to its fall." "The fall over the face of the precipice seems slow and sullen from the velocity of the surface water of this rapid and from the great denseness of the body, and it plunges heavily down with a deep thundering sound which we heard during the previous night at our encampment three and a half miles farther down the river. This ponderous descent, and the heavy, muddy color of the water, conveys a feeling of weight through the eye to the senses, which is relieved by the lightness and airiness of thin clouds of white vapour and amber-colored spray which ascend from the basin at the bottom of the gorge in curling wreaths, curtaining the lower portion of the fall, and through which the basin was only seen at intervals when its surface was swept by the fitful gusts which swept up the glen. The velocity of the water of the rapid was about 9 feet per second and its depth 10 feet. A tumblerful of the turbid water deposited $\frac{1}{50}$th of its bulk of a fine reddish clay not calcareous." Captain Newbold also mentioned what must have been a tremendous flood, seven years previous to his visit, in which the water rose so high as to submerge three of the flight of stone steps leading up to the largest of the temples on the right, or south bank of the river. He also alludes to some large fissures in the cliff forming the south side of the gorge, which are really joint fissures, much enlarged by partial sliding forward of the rocky masses. The small hill seen in the background of the view is part of the Deccan trap by which the quartzites are overlaid a few miles to the westward.

As Newbold pointed out, the rate of recession of the waterfall must, in the case of such exceedingly hard rocks, be extremely small; its antiquity must therefore be great, for there can be little doubt that the river has cut all the narrow parts of the present gorge which extends fully a mile backward from the general point of the scarp of the Gokák hills. This scarp, which may

The Gokák scarp.

conveniently be called the Gokák scarp, and the northern and larger half of which is shown in the panoramic sketch, is of great geological antiquity; it must have existed in something like its present shape prior to the pouring out of many, if not of all, the flows of the Deccan trap series. This is proved by the fact that trap-flows low down in the series lapped round the very base of the scarp, and have in part been left there. There can, indeed, be little doubt that the amount of denudation the Kaládgi basin was subjected to before the flows of the Deccan trap period were poured out over it, much exceeded the amount it has lost since it again came under atmospheric action.

Gokák outliers.

Two small, but very conspicuous outliers of the basement conglomerate beds, cap isolated, and very nearly perfectly conical hills, one on either side of the Ghatprábha, where it emerges from the gorge below the falls. The conglomerate beds form sharply scarped table-tops to the two hills, which consist of hornblendic and micaceous schists. The larger one, which rises more than 600 feet over the town of Gokák, was formerly fortified. It overlooks a great part of the quartzite plateau which stretches away far to the south-west.*

Gorge of the Márkándeya river.

Very beautiful cliffs of the same quartzites are to be seen in the valley of the Márkándeya river, two miles south-west of Gokák, and specially in a great ravine, opening into it from the south from the Karabgatti (Kurrubguttee) plateau.† The cliffs are bright red, and contrast superbly with the green jungle

* The scorings on the side of this hill as shown in the panoramic view forming the frontispiece have been a good deal exaggerated by the lithographic artist.

† It is not unlikely that there is an inlier of gneiss exposed in the great ravine in question. I did not enter it when examining the gorge from the north, not suspecting any exposure of other rocks; but the view from above raised doubts in my mind whether the quartzites which form the base of the Márkándeya valley nearer to Gokák had not been cut through by denudation higher up. I was unable to descend into the ravine, as the cliffs surrounding it are perpendicular; and being on the march to a distant camp could not afford time to make a long detour; while no opportunity presented itself of revisiting the place.

above and below them. The edges of the conglomerate beds form mural cliffs round many parts of the Gokák scarp, and from the more rapid weathering, in parts, of some of the schistose beds in the gneiss, large masses of the quartzites and conglomerates have fallen down, and in some places lie thick together on the flanks and at foot of the hills, precisely like the case illustrated by Mr. King in his report on the Kadapah and Karnul rocks,* only on a yet larger scale.

3. *Exposures and sections in the western part of the Kaládgi basin.*

Lower quartzite series south and west of Gokák.

The Gokák scarp dies away northward under the Deccan trap at Arbhavi (Arbhawee), four miles north of Gokák; to the south it forms two bold headlands jutting out eastward, but farther south it is lost, and the beds forming it dip southward and then roll about very variously, but generally at very low angles over a large area covered with low wooded hills on the banks of the great Kelvi† nullah and its tributaries, extending southward to Lakmapoor, and still further to Marihal (Murreehal) and Deshnur (Deisnoor), eastward to Mamdapoor and Nandi, and westward to the Márkándeya river or Padshapoor-Unkalgee valley. Throughout this region the sandstones less frequently assume the character of quartzites, having been exposed to a decidedly lesser degree of metamorphism. The coarser beds, as conglomerates and grits, show but little change, but some of the fine-grained beds, even where lying horizontally, or very nearly so, are true quartzites; where the beds have been disturbed, the amount of metamorphism is in direct proportion to the amount of disturbance that has taken place.

Its characters.

Continued far to the west.

These characteristics of the rocks will be found to extend westward across the Márkándeya river up to the Kakti and Kalkambeh scarps near Belgaum, and up the upper

* Memoirs of the Geological Survey of India, Vol. VIII. Plate III, Fig. 1.

† The course of the Kelvi nullah is incorrectly laid down in sheet 41. Instead of flowing northward from opposite to Buneechmurdee, it really continues its north-easterly course and falls into the great Mamdapoor nullah between Maldinni and Uparhatti (Ooparhattee).

valley of the Ghatprábha, past Konur, Ghorgiri, Mujti, Wantmuri (Wutmooree), Sutgutti, and Daddi, up to the extreme western extremity of the Kaládgi basin at Watangi. Throughout this region there are innumerable sections showing the local development of beds very well, but none giving a good idea of the whole, or even a large part of the basement series of the Lower Kaládgi rocks. The two gneiss inliers of Uranhatti (Oorunbuttee) and Yellapur* would appear to be high points of the old gneissic surface, round which the true basement beds of the series are not exposed. It would doubtless be feasible to work out much more closely the succession and change of beds occurring throughout this extensive region by a series of careful traverses; but it would, under present circumstances, be labor ill bestowed to attempt to work out closely the details of a country exceedingly rugged, and so monotonous in its geological character.

4. *Outlying exposures and sections west of the Kaládgi basin.*

To resume the review of the sections and exposures met with in succession while proceeding westward, it will be seen by the map that the Lower Kaládgi quartzites and sandstones at Watangi are covered up on three sides by the flows of the Deccan trap series. If the ridge of trap which covers the quartzites west and north of Watangi be crossed, the quartzites will be found to re-appear in the valley of the Harankáshi river, and to occupy a very considerable area in that valley, forming an inlier which may be called the Mangaon inlier, from the most important village which stands upon it.

The Mangaon inlier.

No peculiar features are presented by the rocks forming this inlier; they consist of quartzites and grits, mostly dipping northward, or north-by-west, at low angles. They are best exposed in the row of hills which runs east-south-east from Sulgaon on the bank of the Harankáshi river, and joins the trap ridge just before mentioned. The quartzites and grits are mostly pale colored and fine grained, and form a series of beds

* The real name of the village marked Yellapoor in sheet 41 is Musalmari (Moosulmaree).

several hundred feet thick, although both top and bottom of the series is hidden under the trap. Petrologically identical with the Mangaon beds are the beds forming several smaller inliers in the valley of the Vedganga, eight miles to the north-west. These latter lie in the centre of the valley between Yengol and Shengaon, and are four in number, of which the southernmost close to the village of Yengol forms a small but conspicuous isolated hill 200 to 300 feet high. Here all the beds dip north-north-west from 5° to 10°. The other inliers are simply exposures on the flanks of the great ridges.

Inliers in the Vedganga valley.

A great thickness of quartzites and grits of identical character is exposed in a small inlier at Pyah in a side valley two miles west-north-west of Shengaon. In the valley of the Dudhganga are two good-sized quartzite inliers lying north-westward of those of Pyah and Shengaon, of which they must be considered the extensions, both on petrological and stratigraphical grounds, nor can it be reasonably doubted that they form a true link with the very similar series of rocks exposed at the foot of the Phonda ghát, nine miles to the west-north-west. As in the Mangaon and Shengaon inliers, the quartzites and grits of the Waki and Inni inliers are pale colored (whitish, drab, or pinkish) and fine grained. They have been but little disturbed, but roll about at low angles, as 8° to 10°, in various directions, but in both inliers the western edge passes under the trap with a westerly dip of 8° to 10°. The quartzites do not show in the valley of the Bogavati between Waliura (?) (Wulewra) and the top of the Phonda ghát.

Pyah inlier.

Inliers in the Dudhganga valley.

Waki and Inni inliers.

In the Inni inlier, the beds, which are nearly horizontal, cannot be less than from 400 to 500 feet thick, measured from the level of the river. Both here and in the Waki and to a lesser extent in the Pyah inlier, the really light-colored rocks have been blackened so much externally by weathering, and probably in part also by the action of frequent jungle

fires, that it is often difficult to recognize the real nature of detached masses except on close inspection.

5. *Quartzites and sandstones in the Konkan.*

Konkan quartzites of Kaládgi age.

Below the gháts, and especially near the foot of the Phonda ghát, which leads from Kohlapoor to Ratnagherry, is an important development of these rocks, which, as above stated, must, on petrological and stratigraphical grounds, be reckoned as belonging to the quartzite series of the Lower Kaládgi group. The main mass of these rocks, which were worked out by Mr. C. J. Wilkinson, late of the Geological Survey of India, occupies a patch of country, about ten miles square, close to the base of the Western Gháts, but they occur also in a number of detached patches forming outliers on the gneissic rocks and inliers among the overlying trappean and lateritic rocks. These patches are chiefly situated to the south-west of the Phonda ghát and near the sea. Several quartzite-sandstone hills occur in the northern part of the patch, one of which, Salwa hill, attains a height of about 800 to 900 feet. It is capped by a thick bed of pink sandstone which is either horizontal or has a very small dip to the west. There are other high hills or spurs on the edge of the gháts formed of similar sandstones resting on the gneissic rocks, which hills or spurs are capped by the same thick bed of sandstone. The sandstones there dip eastward, the two portions of the beds on the respective hills being apparently the remains of a low anticlinal arch. The position of the trap-flows at the bases of these hills shows that they had been in great measure shaped by erosive forces acting prior to the outpouring of the trap-flows.

Of the other outlying patches of Kaládgi rocks the most important is that on which stands the village of Achura, or Achre, near the mouth of the river of the same name. The sandstones here found form hills to the north of Chindur in which the shales belonging to this part of the series are not well seen; but better sections are to be found in the river banks, where the shales are seen associated with the lowest sand-

stone beds. The dip of the beds here is generally west-20°-south at an angle of 20°. The sandstone hills east and south-east of Achre attain a maximum elevation of about 300 feet, and exceed the surrounding laterite hills. The sandstones are mostly white in color and of saccharoid texture, but other colors are also to be seen.

Extensions of these rocks appear below the Deccan trap and laterite at different points all round the Achre patch, but chiefly to the north and south, *e. g.*, at Mongia (Monge), and at the mouth of the small river falling into the sea at Meetbaon (? Mitgaon) to the north, and at Chindurwari to the south. South of the Bhuruthgarh river the Kaládgi beds, here consisting of sandstones and shales, are exposed in numerous sections in the valleys cut by the tributaries of the Mussoora stream, an important affluent of the small river just named. In the ravines north of the stream platey argillaceous shales only are to be seen. These shales are of dark blue or slate color when freshly broken, but weather to a very light blue or slate color; in texture and fracture they vary from hard and conchoidal to soft and soapy. They are generally overlaid by sandstones, but are also interstratified with thin seams of the same rock.

The sandstones appear also on the coast at Malwan and in a couple of small outliers on either side of the Kodal river four miles south-east-by-south of Malwan. The last and most southerly outlier of the Kaládgi rocks in the Konkan occurs at the southern extremity of the great Bhekurlé spur of the ghâts, 8 miles south-west of Ramghát, just above the divergence of the ridge into several minor spurs. The Vingorla rocks and other small islands off the coast all consist of the very hard rocks belonging to the quartzite series.

6. *Sections of the south and south-east sides of the Kaládgi basin.*

Kakti plateau.

We now return to the Kaládgi basin and take up the series of sections to be seen along its southern boundaries, beginning at Kakti, north of Belgaum. The quartzite series

here forms a scarp, the base of which is obscured by a thick talus which abuts upon a broad alluvial flat accumulated in the valley of the Márkándeya river above the gorge by which that river now flows through the congeries of hills and small quartzite plateaux lying between Kakti and the Ankalgi valley. This scarp is merely the north-westerly continuation of a scarp forming the boundary of the quartzite plateau lying north of the Belgaum valley, and along the entire base of which the underlying metamorphic rocks are to be seen. From the relative position of the trap-flows forming the base of the great flat-topped hill known as the One Tree hill, and lying north-east of Belgaum, it is clear that unless there has been some subsequent dislocation of the two rock-series (of which there is not the slightest evidence), the Kakti scarp was formed prior certainly to the outpouring of those particular trap-flows and not improbably prior to the very earliest. It is not unlikely that this scarp extends far to the north-west under the overlying trap. The form of the ground at Rajguli (on the Tambraparni (Tamburphurnee), a large feeder of the Ghatprábha rising close to Ramghát), at Naiseree, at the scarp north of Ajra, at Yengol in the valley of the Vedganga, and at Waki in that of the Dudhganga, suggests the idea that the scarps there seen are really the great boundary scarp of the westward extension of the Kaládgi basin, although the base of the scarp is not sufficiently uncovered by denudation for the underlying metamorphics to be seen.

Kakti scarp of pre-trappean age.

Both above Kakti and along the south scarp above Kalkhambeh (Kulkhumbeh), a succession of conglomerate and grit beds, with some compact quartzites intercalated between them, are seen to dip north or north-east at low angles. Farther in, *i. e.*, north, other gritty and pebbly beds are met with overlying the beds which form the scarp. These latter extend all across the slightly inclined plateau to the gorge of the Márkándeya near Nandi, north of which come in other quartzites, which extend up to the valley of the Ghatprábha near Sutgatti (Sootgutti) and Wantmari (Wutmooree).

The very gritty and conglomeratic character of the beds in the Kakti plateau changes gradually eastward, so that near Hoskatti and Hanbarkatti* quartzite beds predominate. The denudation of this part of the Kaládgi basin prior to the trap outpouring was very great, as shown by the position of the quartzite beds capping the Budnur (Boodnoor) hill, which is an inlier of gneissic rocks within the trap area. A fine section of the quartzites which there form the basement of the Kaládgi series is to be seen in the valley north of Sidapur, where the Budnur nullah enters the Kaládgi basin by a rather picturesque gorge. The beds dip 12° north-north-east.

Sidapur gorge section.

At the next gorge eastward from Sidapur, the edge of the basin is more than usually uptilted, and the quartzite beds have a dip of from 30° to 35° north-east.

Murgod section.

The next section, or, more strictly speaking, exposure of the series which is noticeable occurs at Murgod (Moorgor). Here a set of quartzite beds forms the actual base of the series, and is overlaid by a set of conglomerates with a sandstone forming the surface of great part of the plateau east of the village. The surface of this has been greatly broken up by weathering probably, but re-formed into a kind of breccia pavement by cementation with a ferruginous (quasi-lateritic) cement of apparently sub-aerial origin. The pebbles included in the conglomerates are mostly of an older quartzite, probably of gneissic age. The beds forming the plateau east of the village rise eastward toward the apex of the remarkable flat dome culminating in the Kathárigarh (Kuttargarh) Droog hill (a trigonometrical station, 2,844 feet high). The arch of the dome was by some force or other

Kathárigarh dome.

* The Atlas Sheet is here incorrect; the Hanbarkatti nullah flows hence nearly due east into the Budnur (Boodnoor) nullah, and not north-north-east into the Wanur (Wunnoor) nullah.

fissured in several lines, radiating from the apex, and along these fissures deep valleys were subsequently eroded right through the mass of the quartzites and deep into the underlying granite gneiss. Beyond Katháriqarh eastward the quartzites sink down rapidly into the valley of the Benakatti nullah, a tributary of the Malprábha from the north-west.

From the summit of Katharigarh a very extensive and instructive panoramic view is obtained, which greatly aids the observer in understanding the geological structure of the country round about.

Sogul chines and falls.

A stream which rises in the southern radial valley runs southward through a depression in the quartzite boundary ridge and forms a very picturesque waterfall in a semicircle cut into the hard quartzite conglomerate. The fall is 50 or 60 feet high over a vertical precipice, in which the character of the conglomerate is admirably displayed. Above the principal fall are two minor ones forming a very pretty spot with the aid of an old Jain (?) pagoda and a small shola-like patch of forest. The village of Sogul lies at foot of the scarp below the fall. The matrix of the rock is very pale, reddish-brown or purplish in color, and contains among other pebbles numerous ones of bright red jasper derived from some of the hæmatitic beds of the Malprábha valley.

The southern boundary of the Kathárigarh erosion valley is formed by a considerable fault which runs west 29° north, and has caused an upthrow of the beds on its southern side. The fault extends along the southern side of the deep and picturesque ravine north-west of Karlhutti.

Naul Tirth, the gorge of the Malprábha.

Nine miles east-south-east of Sogul lies the gorge by which the Malprábha enters the Kaládgi basin, a place of great beauty and of great sanctity in the eyes of the Hindoos, by whom it is called the Naul Tirth, or peacock's bath, from a legendary event by which the gorge is said to have been miraculously

J. Schaumburg, Lith.

QUARTZITE TOR IN THE GORGE OF THE MALPRABHA.

formed.* The gorge forms a true "cañon," about 300 feet deep along the upper or south-western half, which is also extremely narrow, not more than 50 yards wide, if not considerably less, and with not an inch of margin between the water, even in very moderate floods, and the vertical walls on either side. During great floods the water rises from 30 to 40 feet in the gorge, and flows with great impetuosity, forming numerous pot-holes of great size and depth, which, as at the Gokák falls, are at certain seasons largely resorted to by Hindoos anxious to wash away their sins in the purifying river. In its lower or northern half the gorge widens considerably, and the sides decrease in height, till the quartzite beds die out in a level flat which stretches away for some distance to the north-east. A very remarkable isolated rock stands below the left bank on a steep slope above the present water level, near the top of the lower half of the gorge. This rock, which is figured in the annexed sketch (Plate IV) has remained *in situ* in a remarkable way when the upper and lower parts of the beds of which it is made up have slid down into the torrent below and been broken up and swept away. There are no signs that the waters of the river ever reached the elevation at which this remarkable tor stands, but if it ever did, the waters of the Malprábha must have been ponded back for miles above the upper mouth of the gorge, and have formed a great lake of which no distinct trace now remains. The hard quartzites are extremely polished in the bed of

* The legend above referred to relates that on one occasion a peacock hard pressed by its pursuers, and well-nigh worn out with fatigue, was unable to fly over the chain of hills which rises north of the great "black plain." In its terror it cried out piteously when seated on a large rock, which to this day is pointed out to the faithful. The cry of the agonized bird was heard by the deity of the Malprábha (locally called Ganga), who took pity on the fugitive, struck the rocks, and clove a passage through the hills by which it escaped. Finding the newly-made passage convenient, the goddess adopted it as a channel for her own waters, and has used it ever since. Owing to the pious benevolence of the river deity, the river at this spot is supposed to have great efficacy in cleansing moral pollution, and is accordingly largely resorted to at every new moon by devotees who bathe in the numerous pot-holes when the river is low. I am indebted for this interesting legend to my friend the Rev. J. S. Hawker of the London Missionary Society at Belgaum, a great lover of Indian Folk-lore.

the river within water reach, so much so that walking becomes very difficult, indeed, in places positively dangerous.* The polished surface is in most places covered with a thin film of dark, greyish-black color (hydrated peroxdide of iron?), as if black-leaded, contrasting strongly with the delicate and beautiful pale reddish and pink of the quartzite rocks where unstained.

None of the other numerous sections of the basement division of the Lower Kaládgi series equal the Naul Tirth gorge in clearness; bed after bed may be traced upward or downward by the eye, and no doubling of the beds is visible. The dip varies from 10° to 15°, averaging as nearly as possible 12°, and the prevalent colors seen are pale shades of light reddish, and pinkish and drab, with a few beds of light, bluish-grey color. Near the base some of the quartzite beds are of bright red salmon color, or even of pale peach-blossom color. Many minor beds among the quartzites are very pebbly—perfect conglomerates in fact. Among the included pebbles and fragments are many of red and grey jasper, derived from hæmatite beds in the gneiss. Pebbles of quartz and other quartzites, also of hornblendic schist and of pistacite, are common among the inclusions to be observed. The quartzite beds often contain isolated pebbles, which, especially when they consist of red jasper, contrast strongly with the generally uniform texture of the matrix.

Taking the length of the section at 1¼ miles directly across the ridge, the total thickness of quartzite and conglomerates cannot be estimated at less than from 1,200 to 1,300 feet, the average dip of 12° being perfectly steady throughout the greatest part of the section. Most of the faces of cliff exposed in the "cañon" correspond with some one or other of the principal lines of jointing by which the whole quartzite series is permeated.

* The tumbled rocks in the bed of the gorge are so highly polished that a couple of lively terriers that went scrambling about among them repeatedly got into places whence they were afraid to stir and cried piteously for help, failing which they slipped about and fell, in a manner not at all common to such four-footed animals.

To the north the quartzites dip under a thick series of clay schists which occupy the flat immediately north of the gorge extending up to a low quartzite ridge formed by a reappearance of the upper part of the basement series in a sharply flexed anticlinal which abuts on the left bank of the river close to Manoli (Munolee), forming a well-marked elliptical head ere disappearing again under the schists. To the west this anticlinal sinks very low, but then rises again and joins the south-east extension of the Kathárigarh plateau south of Madlur. The large village of Manoli stands upon the clay schists, and is principally built of a flaggy variety of the same, which are exposed in the dry season in the bed of the Malprábha immediately opposite the village.*

Overlying clay schists.

Manoli anticlinal.

Eastward from the Naul Tirth the boundary of the Kaládgi basin is formed by a line of bluff quartzite hills, showing here and there precipitous scarps. The bases of the scarps are everywhere obscured by talus, and the underlying gneiss rocks are very seldom seen. No section of special interest is seen for many miles, though the quartzites are well cut into in various places, as in the Sure-Kollu ravine six miles south-east-by-east of Ramdurg, and at the gorges by which the Malprábha leaves the Kaládgi basin at Biddugal. In the former section the quartzites form a fine cliff from 200 to 250 feet high.

Sure-Kollu section.

The several outliers of the quartzite series which occur south of the Kaládgi basin are the Parasgarh, Chulki (Choolkee), Chik Nargund, and Nargund hills.

Southern outliers.

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* Manoli is a place of some historic interest, for it was here that General Wellesley first came upon the notorious robber chief Doondia Wáug, whose strong entrenched camp immediately opposite the village was at once attacked and taken by a cavalry charge, when some thousands of the panic-stricken freebooters rushed into the swollen river, and great numbers were drowned.

Parasgarh inclined plane.

The quartzites of Parasgarh hill are faulted against the gneiss along their northern boundary, and form a great inclined plane, with an average dip of 7° north. In many parts the surface shows vast sheets of perfectly bare rock. At the south-west corner of the plateau stand the ruins of the very ancient fortress of Parasgarh, perched boldly on the very edge of the precipitous scarp, and commanding a fine view over the plains towards Dharwar. A remarkable spring, said to be perennial, occurs in a cave about 200 feet below the edge of the scarp, but still within the precincts of the ancient fort. The quantity of water is so great, and the position of the spring so close to the edge of the western scarp, that it is clear the water must find its way thither by flowing through the great joints from the highest brow of the inclined plane eastward of the old fort. The cave is a rudely lenticular hollow between two beds of quartzites near the base of the cliff, and the approach to it from above is guarded by various walls to enable the garrison to visit the spring in safety from enemies in the plain below. The occurrence of such a spring in the quartzites is quite unique, and its existence in such a strong position was very likely the chief *raison d'être* of the old stronghold, which still gives its name to the taluq, though the place itself is now quite abandoned, and the taluq cutcherry and other offices are now all located at Saundatti (Sumodutti), three miles to the north-west. On the extreme eastern end of the Parasgarh outlier stands the Hirakumbi (Heerakoombee) trigonometrical station, 2,572 feet above sea level, and 500 to 600 feet above the adjacent plain.

Parasgarh spring.

Chick Nargund hill.

Chick Nargund hill is also capped by an inclined plane of quartzites dipping from 30° to 35° north-by-east. The north side of the inclined plane is probably faulted against the gneiss, but the base of the hill is so much obscured by talus cemented into a breccia by infiltration of tufaceous kunkur that it is impossible to trace the fault.

Nargund hill outlier.

Nargund hill, a very conspicuous object for miles around, rises abruptly from the "black plain." The lower part consists of schistose varieties of gneissic rocks which are capped by several hundred feet of typical quartzites, forming a narrow plateau with a very fine series of precipitous scarps all round. The plateau is about a mile long by a furlong wide, and being elaborately fortified, was in former times one of the finest and most important strongholds in those regions.*

The contact of the basement bed and underlying gneissic schist may be seen on the path leading up to the fort. At that particular spot the schist is a grey to purple gritty micaceous schist, dipping 50° to 70° east-by-north. On the schist is a bed of brecciated quartzite conglomerate from 1½ to 4 feet thick, overlaid by bluish "waxy" quartzite, and this again by buffy and pale salmon-red beds. On the summit the beds dip from both ends towards the centre with a slight southerly inclination at angles of from 5° to 10°. The western end is rather the higher, and cannot be much less than 1,000 feet above the plain.

Boundary between Biddugal and Telluskode.

The base of the long quartzite ridge stretching from Biddugal, where the Malprábha leaves the Kaládgi basin, to Telluskode, where it again enters the basin, is nowhere exposed; the thick cotton soil deposit of the "black plain" extends close up to the hills and is itself covered by the sandy talus resulting from the decomposition of the quartzites.†

* Nargund fort resisted the efforts of Tippoo Sultan's army for a long time in 1785, and finally surrendered only on favorable terms being offered, but not observed, by the treacherous conqueror. The Brahmin Rajah of Nargund broke into rebellion in 1858, relying on the strength of his castle, and murdered Mr. Manson, the Assistant Political Agent, but having forgotten to provide a proper supply of powder, made no defence of the fort. He fled, but was overtaken, and eventually hanged at Belgaum. The fort was dismantled and in part blown up.

† The "dirty" breccia show at various points, *e. g.*, a little to east-south-east of Somunkop, east of the high road running from the left bank of the Malprabha at Goankop, northward to Bijapur and Sholapur. Again, further east near Lakmapur and Mullapur, and very strikingly at Telluskode, the ford over the Malprábha on the road from Bádámi to Gadag (Gudduck).

The central part of this ridge near Khánápur and Banknuri (Bunknuree) is much more uptilted than either end of it. At Biddugal abovementioned the beds dip 35° north-west; at Khánápur from 50° to 60° north-east-by-north; at Banknuri from 60° to 75°. The dip decreases to 35° to 45° at Lakmapur, and to 30° at Chinrasavi, where the quartzite beds cross the Malprábha. Further east the dip decreases rapidly to 8° north on the plateau above Belur, and then the strata become horizontal, or roll about but very slightly, where they form the plateau capping the line of hills stretching away to Gajendragarh. The beds here are generally grits, or very compact sandstone, assuming the character of quartzites, however, where they are even slightly upturned. Conglomerates, though not altogether absent, are not very common in this quarter. The same characters hold good in the outliers north of the Gajendragarh hills around Gudur.

Belur and Gajendragarh plateaux.

Gudur.

The predominant colors are pale in tint, whether they are drab, grey, purplish, reddish, pink, or brown. But there are here and there exceptionally dark beds of sandstone, *e. g.*, a bed of dark-brown sandstone at Wukund (Wookoond). One of the best sections in the Gudur hills is that immediately east of the village on the pathway up to the old fort which is perched on the north-west angle of the principal plateau.* The beds here exposed in a very steep scarp are pale drab, brown and reddish-brown thick-bedded sandstones with occasional layers of pebbles, and pebbles scattered sparsely throughout the mass of the rock. Some of the more gritty beds show much false bedding. The sandstones occasionally show some fine scarps, which, like the quartzite scarps in other quarters, show much bright-red ferruginous staining. Such scarps are to be seen at Parsapur and Hanam-

Hanamságar and Gudur plateaux.

* The nullah flowing past Gudur from Murudi (Mooroodi) is not correctly shown in the Atlas Sheet (No. 41), for it really runs well south-westward of the villages instead of two-thirds of a mile eastward as shown in the map.

sagar eastward from Gudur, also at Gajendragarh and in the valley to the north-west of the town.

The fact that where the sandstones are horizontal, or nearly so, they are but little altered, has already been mentioned. A very marked example of their changing to quartzites where upturned to a considerable degree occurs a few miles westward from Gudur at Rangasamudra, a village not shown in the Atlas Sheet (41); but which lies at the northern end of the gorge by which the large Nilawágal nullah flows across the eastern end of the quartzite-sandstone area extending from Bádámi eastward across the Malprabha and which may conveniently be called the Wukund plateau.

Niláwagal nullah gorge.

The eastern edge of this area is formed of sandstone beds lying slightly inclined to the south-west. Very soon, however, the beds dip westward some 20° to 25° towards a synclinal axis, while at the north end of the gorge they dip south-south-west 65°, and in both cases assume the character of typical quartzites. At the north end of the gorge the change may be traced all along with perfect ease, as the beds form a bare scarp running south-eastward. The eastward continuation of the same beds is seen capping the rather high plateau south of Gudur in a perfectly horizontal position. The gorge of the Nilawágal nullah coincides with the axis of the synclinal curve above named. The central part of it is very picturesque from the recurrence of a great thickness of the chocolate-coloured breccia ("dirty breccia" in part) so frequently seen in the north-eastern part of the Kaládgi basin, which has been worn into high and rugged rocks and cliffs rising mainly on the left (western) bank of the nullah. Westward of this nullah the beds resume their relative horizontality, or roll about at very low angles, and again present the simple hard sandstone character.

Wukund plateau.

North of the Gudur nullah is another extensive plateau of sandstones, partly horizontal, partly rolling about at low angles, the mineral character of which is much the same

Plateau north of Gudur.

as that of the Gudur and Hanamságar outlying plateaux. This plateau is connected with the Kaládgi basin by a narrow strip branching from its north-western extremity, and crossing the bed of the Malprabha close to the village of Aiholi (Iwullee), famous for the very numerous and beautiful Jain temples still remaining there. These temples, which are built of sandstone and quartzite-sandstone quarried in the adjacent hills, show how admirably many of these building stones are suited even for highly decorative purposes. The surface of the granitoid gneiss on which the beds forming these different plateaux were deposited was a highly irregular one. This may be well seen in the picturesque valley running from Goodoor south-south-east to Murudi (Mooroodi), for the sandstone plateau, while maintaining a very even upper level, shows in the scarped edges very variable thickness, and many of the upper beds are seen to overlap the lower ones and to rest in part directly on the gneiss. Thus the basement beds at Murudi and Ganuduhal form the middle of the series exposed on the north side of the plateau.

Jain temples of Aiholi.

Gudur-Murudi valley.

Turning westward and recrossing the Malprabha, a remarkable plateau of quartzite sandstones and gritty beds is reached to the eastward of Bádámi. These beds may be best studied at Bádámi itself in the two fortified hills rising north and south of the town, which, as already mentioned, occupies one of the few spots in the South Mahratta country east of the ghát region which deserve to be called beautiful. It occupies the mouth of a horse-shoe bay in the hills, the space behind the town and the surrounding cliffs being taken up by a deep tank and a not very wide talus sloping to the water's edge. The cliffs are chiefly formed of pale buffy thick-bedded quartzite-sandstone with purple laminæ stained red externally in many places. The beds dip westward at a low angle, and parts of them seem to have slid westward a few feet towards the plain, being separated from the main mass by great joints which now form deep chasms severing different parts of the hill completely from the rest. If the chasms were

Bádámi plateau.

J. Schaumburg, Lith.

THE NORTHERN HILL-FORT AT BADÁMI.

really formed by the sliding of the front of the cliffs, the slip was probably due to the presence of some softer thin shaley bed which was acted upon by springs, and the superincumbent masses moved down the slope impelled by their own weight. These great chasms serve as the inner approaches to the upper parts of both forts. One of the principal of those in the north hill is shown in the annexed view (Plate VI) sketched from the most easterly of the cave-temples cut into the face of the southern cliff. This temple is apparently of Buddhist origin, the figures carved in great number on the walls and pillars being all or very nearly all figures of Buddha in various positions. The other three cave-temples are unquestionably of Jain origin and well worth visiting, as they contain many very spirited groups of figures.*

The gritty beds which form the top of the plateau are admirably displayed along the path leading from Bádámi to Nandikesur (Nundeekesur) in the Malprabha valley, past the very picturesque old Jain temple of Magandi, within the precincts of which rises a very fine spring.

The gritty beds show very extensive false bedding, so much so that the actual lie of the beds is locally very difficult to make out. Beds of similar character and the unquestionable extension of the Bádámi set occur to the west-north-west and north, *e. g.*, at Alludkatti, Karadigudda (Kureedeegooda), Belgiri, Hudgal, Kuteni Keri (Kootenee Kehree), and Rugkapur. Further west the character of the beds becomes more sandy or even shaley.

North-east of the Bádámi plateau, the beds being more frequently disturbed and upturned, quartzites are more largely met with. About a

* They have been briefly described in a work by James Bird, Esq., M. H. A. S., &c., called Historical Researches on the origin and principles of the Buddha and Jaina religions, illustrated by descriptive accounts of the caves of Western India, &c. Bombay, 1847 Mr. Bird gives A. D. 933 as the date of these caves. Some of the statues show a great deal of spirit and boldness in their attitudes.

mile east of the great tank at Kendur (Khenthoor), the boundary between the quartzites and gneiss is formed by a line of fault which extends for about three miles. Some fine cliff scenery in which the quartzites are exceedingly well shown occurs near the eastern end of the fault.

Faulted boundary south of Kaládgi basin.

The boundary of the Kaládgi basin in this quarter is extremely sinuous, the denudation of the basement beds exposing the gneissic rocks in various deeply cut valleys forming bays running far into the area of the basin. The lie of the basement beds along this part of the boundary is generally rather undulating, but considerable areas of rather disturbed strata alternate with equal areas in which no disturbance took place, and the strata are horizontal, or but very slightly inclined.

Sirur plateau.

To the north of the small town of Guledgudd (Gooludgoodapeit) this variation of position of the strata is very well marked. The surface of the high plateau lying between Sirur and Guledgudd, which is very undulating, is over a large extent of it coincident with the true surface of the beds exposed. Within a mile of Sirur the beds suddenly roll over northward and dip under the limestone and shale series, which here approaches near to the edge of the Kaládgi basin. The hills which extend westward from the plateau form a low anticlinal arch which extends several miles westward and dies away under the limestone and shale series at Kattigiri (Kutteegeeree). Eastward of Sirur the basement series form a ridge of considerable height with a dip of 30° to 35° north which extends to and crosses the Malprabha river at the village of Ramdhal, where there is a beautiful show of rippled quartzites of reddish color resting on beds of very handsome purple breccia, which in their turn rest with marked unconformity on the gneissic rocks, here consisting of grey and reddish-brown schists and jaspery hæmatite schists, which latter doubtless were the source of the materials seen in the breccia. A remarkable set of breccia beds forms the very base of the Kaládgi basin just where the new high road between

Ramdhal section.

Sirur and Guledgudd passes on to the gneiss area. The Ramdhal breccia beds join those which lap round the great hæmatite hill rising on the south boundary of the basin about half way between Ramdhal and Amingarh. The great number of bright red or banded fragments of jasper which occur in the beds render them equal in beauty of color to those described in the Adumurunhal section (page 79).

7. *Sections inside the Kaládgi basin.*

This last section concludes the series in the circuit round the boundary of the basin, but there are several sections to be noticed lying well within the area of the basin. In some of these the horizon occupied relative to the series as a whole is very doubtful, partly from imperfection of the section displayed, partly because the space intervening between that and other sections is obscured by overlying formations.

The extension westward of the Bádámi quartzite-sandstone beds has already been mentioned. By their weathering they give rise to a vast amount of extremely sandy soil forming a considerable talus at the base of the different groups of cliffs and isolated rocks. The quartzite-sandstone beds lying in the triangle formed by the villages Nilgundi (Nelgoondee), Bilgiri (Belgerree), and Kerur (Kehroor) form an undulating plateau, and are so deeply cut into by numerous nullahs as to render the country very rugged. As they extend westward the beds change in character and become much more sandy, often indeed passing into friable shaley sandstones, which in some places are overlaid by a thin bed of reddish quartzite. This arrangement is very well displayed in a flat-topped hill crowned by a little hamlet called Yenklapur, two or three miles south-east of Kerur, and again in a low hill north-north-east of Malgi. In the latter case the upper quartzite is capped by grey limestone, and this again by an outlier of Deccan trap. The limestone is unquestionably an outlier of the great limestone series, which is largely developed a few miles to the north. The shaley

Shaley sandstone.

Malgi hill.

sandstones both at Yenklapur and to the north of Malgi are mostly greyish, drab or pale-grey in color.* They are well seen further north-west in the Kallubenkehri nullah and to the west at Fakir Budihal and Hoskuttee. They also cover a large area to the south of the low and irregular anticlinal which the watershed between the valley of the Malprabha on the south and that of the Gatprabha and of the Kerur-Guledgudd nullah on the north.

Rapid weathering of shaley beds.

They form numerous low hills and undulating stretches in the triangular area lying between the villages of Redd Timapur (Reddee Temehpoor), Halgiri and Somankop. The rapid rate of weathering of some of the shaley beds near Reddi Timapur and in the sides of the Hehwulkode valley to the north has given rise to much falling in of the overlying quartzites, which form a plateau locally. The same has been the case with the drab shaley beds and overlying quartzite sandstones north and north-west of Woblapur (Woglapoor). The drab shaley beds are to be seen underlying the local upper quartzite at Mudianur (Moodeeanoor), south-east of Woblapur, and at Khánápur, five miles north-west-by-west of the former place. The shaley series may be traced further westward, in the valley of the Narsapur nullah, beyond which they disappear under the trap and the Sidanhal limestone patch, but re-appear three miles further to the westward, near Korkop, where many small sections of them are seen in various nullahs and wells. They are then again lost under the trap, but re-appear in the Kodliwad (Kodlewar) valley, six miles further to the north-westward. Here, and in the several valleys opening into it, the shaley

Shaley beds in Kodliwad nullah valley.

* A singular concretionary mass of earthy red hæmatite which resembled most strikingly the fossilized trunk of a tree was observed in a field a little to the north of Malgi lying half exposed in the drab shaley sandstone. This mass was rudely cylindrical in shape, of a rich purple color, from 6 to 8 feet long, and about as thick as a man's leg. Internally it was tesselated (cubically concentric) in structure, and showed no trace of being organic in origin.

series is very extensively developed, and extends yet further westward to the neighbourhood of Nandi, on the banks of the Mamdapur nullah.

The lower part of the shaley series probably represents some of the quartzites elsewhere, for the basement quartzites, as exposed on the boundary ridge between Mamdapur and Betgeereh, are much thinner than in most other sections.

Manoli clay-schists.

The clay-schists, described as overlying the basement quartzites at Manoli, would appear from their position to be the equivalents of the shaley series just described. They extend from some distance north-west of Yergatti (Yergutteh), a stage with a traveller's bungalow on the Belgaum-Kaládgi road, south-eastward to the Malprabha at Manoli, and across that river into the spurs of the hills running north-east parallel with the river, and are lost, *i. e.*, pass into quartzites or sandstones, among the hills south-west of Ramdurg. To the northward of the clay-schists, *i. e.*, overlying them, comes in sometimes a "dirty" hornstone breccia, similar to those occurring in the north-east corner of the Kaládgi basin; sometimes a set of highly silicious (cherty) limestones, whose extension is in great measure masked by the great accumulations of cherty débris derived from the weathering of the cherty beds, together with great spreads of cotton soil and also of sand formed by decay of the silicious beds on the higher grounds.

Silicious limestone and hornstone breccia.

These silicious limestones appear to be distinct from the great limestone formation occupying the Ghatprabha valley near Kaládgi, but the sections connecting the two sets of limestones are so bad and obscure that the question cannot be considered as one positively settled; and the area the cherty limestone beds of Yergatti (Yergutteh) and Ujenkop (?) (Oojenkop) occupy, is not shown separately in the sketch map which accompanies this report. They extend from Ujenkop south-eastward to Jakkabal on the Malprabha, north-east of Manoli, and are connected doubtless with a

patch of similar character occurring at Goraganur further down the valley of the river. A similar limestone, in a relatively corresponding position, shows to a small extent south of Kolchi in the Ramdurg State. The limestones are principally grey or dark-blue grey in color, the lamination is wavy, and, the whole mass highly silicious; many laminæ are entirely silicious, and, being often one to two inches in thickness, form a very large proportion of the whole; the texture varies from waxy to sub-crystalline, and thence to granular (saccharoid). To the west of Yergatti the limestone beds roll about a good deal in low reefs, and form a rocky wilderness six to eight square miles in area westward of Yergatti. The "dirty breccia" is not seen over this area. To the north-east of Yergatti are some beds of pink and pinkish-grey limestone of less silicious character.

Limestones west of Yergatti.

Near Bussurgee (Bassargi) the dirty breccia shows very rich brown hæmatite to be the cementing material of the comminuted chert fragments. This hæmatite and a richly (red) hæmatitic sandstone, which overlies the limestone at Goraganur, furnish the ore smelted on a small scale at Tagginal near Manoli.

Iron ore at Bassargi.

Overlying the silicious limestones and "dirty breccia" are a thick series of sandstones, with a few conglomerate and quartzite beds; these occupy all the hilly ground south-west and north of Torgal, and form a low rolling plateau, very stony and barren in character. The tract between Torgal and Kureekol is mostly a rocky wilderness, deeply cut into by various streams and covered with scrubby jungle, which is all that the extremely sandy soil can support. Further north-east, the sandstones are represented by the drab shaley series and the overlying quartzites. To complete the survey of the quartzite basement series, it is necessary to glance at the narrow strips of these rocks which lie north of the long spur of Deccan Trap capping the watershed between the Ghatprabha and Malprabha rivers.

Torgal.

The most westerly of those strips forms a high rocky ridge culminating in the Manikeri (Munneekehree) trigonometrical station, 2,458 feet above sea level.* At the station the quartzite beds, which are of reddish and drab colors, have a north-east dip of from 30° to 40°. At Hulkund the ridge is crossed by a nullah, but rises again to the eastward and forms two conspicuous rocky hills, the southernmost of which dies down in an anticlinal ellipse. The anticlinal character of the ridge is obscure at its western extremity, owing to the great height to which the trap still surrounds the hill; it is very probable, too, that that anticlinal is slightly inverted at that end. The quartzite hill to the north at Chippulkatti is clearly a repetition of the same beds, brought up by a fault running parallel with the Manikeri hill ridge. Rather more than half a mile east of the elliptical end of the anticlinal, other sandstone and quartzite beds are exposed, belonging probably to a rather higher horizon in the series. These form part of a low anticlinal, much hidden by the great spreads of cotton soil on which stand the villages of Biskop (Beeskop) and Kulur (Kooloor). The anticlinal can be traced eastward to Salapur, and to a small but very bold and rocky hill north of Naganur.† East of this hill the anticlinal dies away under the shales and limestones.

Manikeri hill.

The reddish quartzite sandstones forming the Naganur hill are fully 100 feet thick, and but slightly disturbed, the northern dip being only 15° and the southern only from 5° to 10°. North of the hill is an apparently overlying set of quartzites of reddish drab and purplish colors, some beds of which are strongly ripple-marked. They dip north 55°, and this high dip seems connected with some noteworthy features in the overlying limestones, which will be mentioned further on.

Naganur hill.

* The view from the summit is very extensive and interesting. To the west the falls of Gokák are seen distinctly, and the Gokák scarp shows in its entirety and far better than from any other place I know of.

† The village lies nearly a mile south of the spot shown in sheet 41.

From Naganur eastward nearly to Julgiri (Julgeeree), a distance of sixteen or seventeen miles along the boundary, the latter is much obscured and difficult to make out, the Kaládgi limestones in most places presenting every appearance of dipping under sandstones and quartzites, which, from their position and petrological characters, must be reckoned as belonging to the lower or basement series. Actual contact of the two sets of rocks could nowhere be found, even with very laborious search, owing to the thick covering of cotton soil, or sandy talus. From the relative positions of the rocks, a series of faults, or inversions of complicated character, must be inferred; the former of these two conditions of contact is much the more probable, and has accordingly been assumed as the true one in delineating the boundary on the map. The quartzites and sandstone beds seen along the obscure boundary are almost entirely conglomeratic in character, and have a more or less southerly dip at low angles. The greatest amount of disturbance took place at Aniwal (Annehwhal).

Aniwal faults.

From Jalgiri eastward the boundary is normal, the quartzites and conglomerates all dipping northward under the limestone series.

Westward of Kattigiri the quartzites form an anticlinal ellipse, corresponding to that on which the village itself stands, while southward from the ellipse the boundary trends south-west to the Kerur nullah, and makes a wide sweep to the southward and eastward, eventually returning north-westward, and enclosing a large shallow bay occupied by limestones and shales belonging to the third section of the lower Kaládgi series.

The only case of a fault-rock noticed within the Kaládgi basin was a large vein (or reef) of distinctly brecciated quartz running along the line of the dislocation caused by the fault north of Bisnal. It is only traceable for about a couple of miles.

Fault-rock.

SECTION II.—*The Lower Kaládgi limestones, shales, and clay schists.*

The limestone and associated shales are, as already pointed out, restricted to the north-eastern quarter of the Kaládgi basin, and within this limit they are found almost invariably to occupy the lowest ground, rising hardly anywhere into elevations sufficient in size to be called hills. The area they occupy may truly be called a subordinate basin within the limits of the Kaládgi basin, and with boundaries fairly parallel in many parts to those of the great basin. The western boundary of the limestone basin is formed almost entirely by the overlying trap flows. A small number of limestone inliers occur in the trap area, beyond the north-western corner of the limestone basin. Several of these inliers are important from their size. South of the limestone basin are five outliers, two of which only are of moderate size, the other three being very small, while on the north side there are three on the very edge of the Kaládgi basin itself.

The limestone basin.

The limestone basin includes within its area a number of minor basins and outliers of rocks (quartzites, limestones, and shales) lying conformably on it, and forming the upper division of the Kaládgi series.

From the fact of their occupying such low lying positions, these rocks are greatly more obscured by superficial deposits, especially cotton soil and quasi-lateritic gravel and conglomerates, than might be expected from the large area over which they occur. The lower and upper beds are all soft and shaley in character, hence are very rarely well seen in sections, and owing to this difficulty and to the great amount of contortion the beds exhibit in very many parts of the area, even quite near the centre, it was found impossible in the time at command to arrive at any satisfactory conclusions as to the actual relations of this section of the Lower Kaládgi series.

Where the sections are so eminently unsatisfactory, it would be useless to describe any in detail, but the chief varieties of the several rocks met with, and the localities where they are most largely, or best, exposed, may be enumerated with advantage.

Limestones near Kaládgi.

From no point can the limestones be better studied than from the town of Kaládgi itself, which stands upon them, very nearly in the centre of the basin. The beds of limestone are much contorted, and the dips and strikes, therefore, very variable within small limits. The average dip is about north-east, from 35° to 40°. The commonest color is grey in various shades, banded with very wavy bands of grey chert which generally weather of a drab or yellowish tint externally. A very handsome variety occurring north of the cantonment is greyish-black banded with green. It is a very impure, highly argillaceous variety. It is overlaid by grey and underlaid by dirty pink, and this by banded grey limestone. A very beautiful pink and pale-green banded, or clouded, variety was discovered by Dr. Thorp, the Zillah Surgeon, at the northern end of the bazaar, and several large masses raised. The greatest exposures of the rock are east, south-east, south, and north-west of the place.

At Sillikeri.

Capital exposures of the limestone occur about two miles to the south-south-east of the town in the Sillikeri (Shoolehgeeree) nullah, where purple, pink, and white banded, dark-grey and almost black beds crop out with a dip of 30° to 40° north-east-by-east, the dark upper beds being much more argillaceous in character. Another exposure and one of the largest in the basin occurs between the two villages of Sillikeri. Here the grey chert-banded variety of the limestone is very largely exposed on either side of an important anticlinal, which extends for some distance east and west, crossing the Khaleskop nullah to the westward, where it is traceable some hundreds of yards till obscured by cotton soil. Similarly, the extension eastward of the

anticlinal is lost sight of about two miles east-by-south of Heerah Sillikeri.

Sillikeri slaty rock.

Southward of the village of Chik (or little) Sillikeri, and on the southern side of the anticlinal axis, some very argillaceous beds make their appearance among the limestones. Two of these are specially noteworthy, because highly prized for economic purposes; the first is a bed of coarse black clay rock of rather gritty texture and exceedingly tough, quarried for rude flags, which are formed by rude, imperfect cleavage joints running nearly at right angles to the bedding. The second is a bed of very tough and strong grey, slaty, calcareous (?) shale, formerly largely quarried for roofing slates for the public buildings at Belgaum. The rock here shows no signs of true cleavage, but in a similar bed, if not the actual extension of the same, which shows about a mile east-south-east of Hire (Heerah, great) Sillikeri, the true cleavage as contrasted to bedding may be very well studied. The cleavage is strong, and dips 65° to 70° east, while the bedding forms a low flat anticlinal whose axis is east-south-east—west-north-west.

Yendikeri silicious limestone.

To the south of Sillikeri near Yendikeri, the grey beds above described re-appear from under the Khaleskop quartzite hill with a northerly dip of from 45° to 65°.

A mile south of Yendikeri the beds again roll over south, and the lower beds are well repeated. They are dark colored and extremely silicious, besides being full of cherty bands.

Oolitic structure in chert.

Some of these cherty bands have a distinctly oolitic structure, which in some cases shows out quite distinctly on weathered surfaces. Some others show a texture quite indistinguishable from a true quartzite. The southern part of the section is obscure, but the limestones and overlying calcareous shale dip southward against the faulted boundary of the limestone basin to the west of Aniwal (Annehwhal).

Grey color most prevalent.

It has already been pointed out that the greatly predominant variety in color among the limestones is grey of various shades; even where other colors are met with, they are developed to a far smaller extent than the greys, especially the paler shades of grey. The other colors met with are, shades of red (mostly pinkish), pale green, purple (mostly pale), whitish (including pale drab and cream-colored), and bluish. Besides the shows of limestone around and to the south of Kaládgi already described, there are several other places where large surfaces of the rock are exposed under circumstances favorable for studying their lithological characters. The most important of these exposures may be enumerated as follows to the east of Kaládgi and south of the Ghatprabha river.

At Bágalkot.

At Bágalkot to the south-west of the town is a great exposure of beds dipping southward 30° to 40°, amongst which are grey, brownish-grey, greenish-grey, pale-grey, green, brownish-pink, pinkish, white streaked with shaley bands in part, also one bed showing a markedly brecciated structure. Some of the beds show considerable concretionary masses and veins of calcspar of white or greyish-white colors. In some cases these are quarried for the sake of the spar, which is used for various ornamental purposes; this has been done particularly in the beds close to Gaddankeri (Guddungerree), five miles west of Bágalkot.

Brecciation of beds.

In several beds a markedly brecciated condition of the limestone was observed locally, but no signs of disturbance could be detected in underlying or overlying beds to account for this change in the texture.

At Nirligi.

At Nirligi (?) (Neerleghee), five miles to the southward, is a great show of grey beds, forming a low anticlinal with east-west axis to the south of the village. South of Kattigiri (Kutteegeree) the limestone basin forms a deep bay crossing the valley of the Kerur (Kehroor)—Guledgudd nullah; the greater part of the bay is occupied by calcareous shales, or argillaceous shales inter-

laminated with bands of limestone from a quarter to one inch in thickness; the shales being of purple or chocolate color and the limestone pale-bluish or greenish-white. These are largely displayed in the two streams draining the slope east of Mannagarh (Munnaghur). In the lowest part of the bay near the banks of the big nullah at Hungurgee these shaley beds are overlaid by grey and drab limestones, the beds of which are much crumpled.

At Kakkalgaon, three miles north-west by north of Kattigiri (Kutteegeree), are banded grey, greyish-white, and whitish limestones, the latter associated with purple-grey clay rock.

At Hulgiri (Hoolgeeree), twelve miles south-east of Kaládgi, a great number of beds crop up north-east of the village, showing nearly as great a variety of colors as the Bágalkot beds.

To the eastward of Kaládgi and north of the Ghatprabha, to the north of the Arrakeri synclinal valley, is a great show of highly silicious limestone full of cherty bands which often completely obscure the calcareous portions of the beds. Much of the calcareous matter has been removed by atmospheric agency, and the surface of the country is greatly marked by chert debris. The more calcareous beds are best seen along the Sholapore road near Sanag (Sanageh). The small tank shown here in the map presents every appearance of being a natural lake, for it possesses no bund, or dam, and there is no trace of the great volume of excavated materials which must have been piled somewhere had the excavation been made by human agency.

Silicious limestones near Sanag.

Sanag lake basin.

This lake is of interest, as being the only natural one, as far as my knowledge goes, in Southern India.* It is small in size, not more than

* There is one other reservoir of fresh water which I should unhesitatingly regard as a true lake if glacial phenomena were admissible in the Peninsula of India. It is a small sheet of water lying at a considerable elevation in the southern gháts west of Courtallam in a coffee estate belonging to Mr. Roosmale-Cocq of Tuticorin; the bund which retains this very picturesque pool strongly resembles an old moraine.

five or six acres in extent, if so much, and of irregular form, and the water which fills it in the rainy season has no visible outlet. On the south side a spread of silicious limestone shelves down into the bed, but on the other sides the banks are rather steep, and so are the channels through which the water flowing from the Bilgi (Beelgee) quartzite plateau enters the little lake. No information other than that to be gathered by actual observation was obtainable; its apparently true lacustrine character seemed to have attracted nobody's attention.

Concretionary structure of the chert.

Many of the cherty laminæ show delicate, concentrically wavy dark lines, which give the chert an appearance of containing an organic structure. The same kind of structure was observed in chert occupying a relatively identical position on the south side of the Kaládgi basin, a little north-westward of the Telluskod ford over the Malprabha and several other places.

Concretionary structure in limestone.

A grey highly silicious limestone, also occupying much the same horizon in the Kaládgi series in which this quasi-organic concretionary structure is largely developed, covers a considerable extent of ground north of Temapur in the Mudhol State, three miles north-west from the travellers' bungalow at Panchgaum (Punsgaon) on the Kaládgi-Belgaum road. The organic appearance is far stronger in the limestones than in the cherts.

Tolanmatti limestone.

Some three or four miles, eastward from Sanag Lake is another rather important show of limestones exposed chiefly in the bed and banks of the Tolanmatti (Tolanmuttee) nullah. The beds here developed are grey, green and pinkish-white, banded and purple in color, the latter earthy in texture. Six miles east of Tolanmatti, at Tuglihal (Tugehleehal), on the right bank of the Ghatprabha, are purplish-grey beds together with some others which are purple banded with bluish-white.

Forms of weathering.

At Hudelur (Oodehloor), three miles east-north-east of Tuglihal, grey cherty limestone shows extensively. Immediately north-west of the village a large sheet of the rock appears, and presents a somewhat unique appearance from the weathering having formed a continuous surface in the shape of a band of chert an inch to an inch and a half thick, which extends beyond the limits of the unbroken sheet as a capping to various detached patches of the underlying calcareous band. At the bend of the Ghatprabha, a little south-west of the village, is an outcrop of massive, grey, chertless limestone with concretional structure, which has given rise to a very singular appearance in the weathering of the rock surface. The whole surface seen is thickly studded over with low conical eminences rising out of small hollows and strongly resembling large rough-shelled limpets or the top valves of *Hippurites*. Each protuberance is due to a concretional cone, one and a half to two or more inches in diameter and about one inch high. They resemble rather weathered cones of percussion, but it is very difficult to imagine what could have produced percussion in such a position at the end of a very long still reach of the river where no large shingle would be borne along with sufficient impetus even in the highest floods, and such cones of percussion are not seen where other limestones are exposed to very strong currents.

The two outlying patches of limestone north of the Krishna river at Chimalga (Cheemulga) and Dewlapoor consist mainly of the grey cherty variety, but their stratigraphical relation to the beds in the limestone basin proper is very obscure owing to the immense masses of detrital matter and surface soils which mask the face of the intervening tract of country. What evidence there is points to their not belonging to the limestone basin, but to their being a set of beds occupying a similar position to those occurring in the valley of the Malprabha north of Manoli (page 111), which lie between the upper and lower sub-division of the basement quartzite series.

The limestone exposures north of the Ghatprabha and westward of Kaládgi now demand attention. The furthest from Kaládgi lies on the bank of the Krishna a little east of Galgali (Gulgulleh). There and in the bed of the river north of Yedhalli (Yedulleh), and visible only when the stream is low, are two beds of limestone, the upper dark-grey, the lower light-grey in color. The upper is very silicious, with the cherty concretions arranged vertically like so many rude organ pipes and not in layers. The lower bed is remarkable, because the surface, wherever exposed, is "cockled" up into large, flat, elliptical domes 4 to 6 feet long by 3 or 4 wide—an arrangement suggesting a pavement made by placing close together the carapaces of hundreds of huge turtle. This bed re-appears north of the Krishna at Jembigi (Jumbgeh), and presents the same "turtle-back" undulations. In a nullah falling into the Krishna, a little south-west of Jembigi, the "turtle-back" bed is seen to rest on another massive limestone which includes fragments of quartzite. Only a few square feet of this latter bed are exposed. A great show of extremely cherty dark-grey limestone is to be seen in the bank of the Krishna just south of the village. This extends across the river to Budihal (Boodehal). At Gulabal (Goolabal), a mile to the south-west, the chert limestone has lost nearly all its calcareous matter, which has been replaced apparently by a pale-yellow ochrey mineral, and the bed assumes in parts the appearance of a dirty-looking semi-cherty quartzite. North of Galgali in the bed of the river, and resting upon the quartzite beds which here form the great barrier across the Krishna, are some thin beds of impure limestone with intercalated thin bands of chert quartzite (very thin) and the ochrey mineral above mentioned. Some laminæ of white satin spar with very brilliant fracture also occur. The ochrey bands, which are dirty red, yellow and drab in color, and certain white, chalky laminæ which accompany them, are most likely merely decomposed shaley beds. A bed of grey quartzite caps this peculiar succession of beds.

Limestone on and in the Krishna at Galgali.

"Turtle-back" structure.

At Galgali.

In returning within the limits of the limestone basin, little or nothing is seen of the limestones north of the Arrakeri synclinal valley; the country is masked by cherty débris and cotton soil. South of the valley and to the north of Khátarki (Khadurgee) are grey limestones dipping north; close to the village there is an anticlinal axis, on the south side of which the beds are grey, grey and white, and white with pale green and pinkish bandings. These beds extend to the east and west. To the east they cross the Ghatprabha, south of Sirugumpi (Sirroogoopee); to the west they show very extensively between Kop and Chik and Hire Algundi (Heera Algoondee). The variety of tints is here even greater than at Khátarki and Lingapur, as bands of pale-green, pink, white and bluish-grey are also met with. The rocks are well seen over large areas bare of any soil, and offer sections of crumpled bedding of very great beauty and interest.

At Khátarki.

At Kop and Algundi.

There can be little doubt that the great show of beds seen at Antapur and to the east of the Wajarmatti double sigmoid curve of the upper quartzite series is the continuation westward of the beds just described at Algundi Kop and Khátarki. A purplish-grey variety occurs at Antapur, besides the other shades mentioned.

South of the Ghatprabha river and westward of Kaládgi is the greatest continuous area occupied by the limestone series, but great stretches are entirely obscured by the thick beds of cotton soil here prevailing. Proceeding along the south bank of the river, the first beds of limestone are met with west of Shedudhal (Shehdoodhal), two and a half miles northwest of Kaládgi. They are pale pink and green with whitish bands very similar to many beds at Kop and Chik Algundi, to which set they most probably belong.

West of Kaládgi.

Silicious limestone at Chattarband Kota.

At Chattarband Kota (Chutturbund Kotta) silicious beds occur very largely, and form the western extremity of an anticlinal axis stretching away to the east-south-east nearly up to the village of Kujadoni, and very likely continuous with the Khaleskop anticlinal mentioned before (p. 116). Some of the silicious bands are quite cherty, others are indistinguishable from thin-bedded quartzites. The set of grey beds which was noted as occurring at Antapur crosses the Ghatprabha at Jembigi in the Mudhol State, and follows the line of the overlying quartzite beds in all its sinuosities, till covered up by the overlying trap flows between Murgur and Yádwád (Yardwar). As at Antapur, the shades of color prevalent are greys of differing intensity; close to Murgur, for example, bluish-grey is a very common color, together with grey and whitish beds.

Yádwád section.

Many of the same beds are unquestionably seen again at Yádwád and in its environs, where one of the largest shows of limestone in the whole region is to be found. The prevalent beds are grey in various shades, but other colors, such as white-banded grey and white, greenish-grey with pink and white bands, and greyish-green, &c., are also to be found. The beds are mostly seen in the bed and banks of the great Yádwád nullah.

The great plain south of Yádwád is covered by an almost unbroken sheet of typical regur through which rocks only protrude in a very few widely scattered places, so that it is impossible to correlate the several outcrops with an approximation to certainty. A little to the north-east of Monami banded green and white limestone with some white and pink bands occur in small sections.

Western outliers.

In the outliers from the main limestone basin west of Yádwád, the limestones are almost entirely of the grey varieties; large shows of these are to be seen between Hal Yergudri (Hull Yergoodree) and Ouradee, between Bisunkop and Beshatti, at Kulgur (Koolgoor), and between Hass Yergudri

and Temapur. The beds seen in the long valley stretching south from Temapur are reddish, pinkish, and grey and green and brownish-banded. The beds in these outliers are mostly very much crumpled, and the true dip often very doubtful in consequence. Exceptional beds in point of color or texture were noted at Alimatti (Aleemuttee), where a brecciated bed of handsome appearance occurs, the drab limestone being cemented by a purple matrix. Beds of dull reddish, earthy limestone occur to the south-east and south-west of Mannapur, associated with red chert, lumps of which are scattered about on the surface.

Alimatti breccia.

The limestone in the two outliers south of the basin near Sidanhal shows flaggy, purple beds, sometimes rather earthy. They roll about a good deal at very low angles, and are underlaid to the south by beds of cream-colored and whitish limestone which occur south of the Tolagatti (Tolaguttee) nullah. Returning to the main limestone basin by the Belgaum-Kaládgi road, grey and whitish limestones, some of which are very cherty, are crossed for four miles north-east of the Panchgaon (Punsgaon) travellers' bungalow. To the north-west of these is a large show of earthy sub-crystalline beds of reddish and pinkish colors, which dip under the Lokapur synclinal.

Sidanhal outlier.

Sections near Panchgaon.

Further east near Warratsgal (Wurrutsgul) is one of the best of the limestone sections along the banks of the nullah which flows northward to Lokapur. South of the village are numerous beds of grey limestone with a northerly dip of from 30° to 60°, which diminishes further north. North of the village a thick series of banded bluish-grey limestone succeeds. These beds resemble those of Yendikeri; but they are far less cherty. They are lost sight of under the thick talus which surrounds the southern side of the Lokapur synclinal. Southward of Warratsgal in the corner between Naganur hill and the Batkurki (Butkoorkee) hill is a consider-

Warratsgal sections.

able show of grey and purplish limestones. North-west of Naganur village are some very handsome, purplish dove-colored and greenish-banded beds. Some have rippled surfaces, the prominences on which are peculiarly weathered, and show an internal silicious frame-work, giving rise to markings like those on the scales of large ganoid fish, such as *Holoptychius*.

Lokapur sections.

On the north side of the synclinal, these grey and bluish-banded limestones are very largely exposed both east and west of Lokapur, where they make the largest show in the whole limestone basin. These two sets of beds are unquestionably the western extensions of those seen at Yendikeri and Khaleskop and Sillikeri, and of which a large display occurs intermediately in the valley of the Kajádoni nullah to the south of the village of that name. Faint traces of copper in the shape of thin films of the carbonate of that mineral (Malachite) were observed in some grey limestone quarried in the bed of the nullah about three miles south of the village.

Kajádoni sections.

Chipurmatti breccia.

Great quantities of grey limestone, much of it highly cherty, are to be seen in the valleys of the different streams which unite to form the Kajádoni nullah, especially to the west and north of Chipurmatti. About a mile to the north-west of Chipurmatti there are indications of brecciated limestone, pale red or pink fragments included in a dull red matrix, also of a variety with purplish-brown matrix, including fragments of grey slate and limestone; neither variety was seen *in situ*, but numerous blocks had been used as fencing-walls on both sides of the path leading northward to Kaládgi. Nearly along the west side of the Yendikeri nullah are numerous beds of limestone dipping south (? inverted) at high angles; amongst these some grey beds with occasional thin veins of bright cherry-red calcspar. In the bed of the nullah is a stratum of pinkish limestone with delicate green stripes, which have been thrown into most elaborate vandykes by contortion of the beds and give the stone a very

handsome pattern. These beds join those described in the Yendikeri valley, already described at page 117, and are the last requiring mention in the survey of the lower limestone series.

The shales.

The shales which accompany the limestone series are, consequent upon their greater softness and on their position, much less well exposed than the limestones, than which, moreover, they appear to be much less developed. They are most largely developed above the limestones, and indicate an approaching return to littoral conditions in the sea (or lake) they were formed in: the littoral conditions, when fairly at work, having given rise to the overlying conglomerates and quartzites, the great talus formation around which conceals the shales in most places.

Violet or purple shales.

The most striking and one of the most prevalent forms of shale is a soft, earthy, calcareous variety of light purple (violet, chocolate, or lavender color), which is generally seen between the upper beds of the limestones and the overlying quartzites. These are to be seen in numerous sections, *e. g.*, on the west face of the Cromlech hill close to Kaládgi, at Govindkop, east-by-south of the same place; also at Truchigeri (Troocheegeree), east of Kaládgi, and at Anathilli, five miles west-by-north of Bagalkot. At Arrakeri, underlying the northern quartzite wall of the synclinal valley, the (violet) chocolate shales are also to be seen. To the south-east of Kaládgi the purple shales are to be seen north of Kerkalmatti (Kurkulmuttee), where they are highly ferruginous, being richly charged with red hæmatite. At Kakalgaon (Kukkulgaon), half-way between Kerkalmatti and Kattigeri (Kutteegeree), they are again of the ordinary pale-purple color; they form two small outliers capped by thin plateaux of the upper quartzites. They occur largely to the north and north-west of Kattigeri. They show also at Aniwal and Batkurki (Butkoorkee), abutting against the faulted boundary of the lower quartzites.

Purple calcareous shales occur in two or three places at the base of the limestones, as at Bágalkot and in the north-east corner of the

basin between Jerramkunta (Geedrankoontee), and also conspicuously a little to the north of Anegwadi (Hungehdee). They are in all probability very largely developed in the eastern corner of the Kaládgi basin, north-east of Sirur (Seeroor), for they are rich in iron, and in weathering give rise to a quasi-laterite, both gravelly and conglomeratic, both of which varieties occur in immense abundance near Sirur, and completely mask the boundary between the limestones and underlying quartzites.

Near Sirur.

Shaley beds occupying an uncertain position with regard to the limestones occur half-way between Hulgiri (Hoolgeerree) and Kerkalmatti. They are in color bright red, reddish, purple, chocolate, grey or ochrey yellow, and are partly calcareous, partly arenaceous in character. They roll about greatly within a small area dipping from 15° to 60°.

Variegated shales near Hulgiri.

Another set of shaley beds whose position is uncertain occurs in the Kaládgi nullah; they are of buff, yellow, and orange colors, and roll about much at low angles. It is doubtful whether it underlies the whole limestone series, or whether it occupies some intermediate position between the different limestone sets.

Near Kaládgi.

Quartz reefs and veins.

But few reefs or veins of sufficient size to demand notice occur in the Kaládgi limestone basin, and even small ones are by no means common, and none offer any points of special interest. The largest of them occurs at Kakkalgaon, ten miles east-south-east of Kaládgi, and forms two low ridges (divided by a break), running east-by-south in the axis of an anticlinal roll in the limestone.

A considerable number of small quartz veins occur close together in a patch of doubtful schistose rock which stands up among the limestones a little north-east of Naganoor hill. The schists which have a strongly gneissic aspect

Small veins north of Naganoor hills.

appear to be argillo-talcose, and are full of small rhombohedral crystals of limonite, pseudo-morphous doubtless of some other mineral (? calcite). The quartz veins also enclose some of the crystals in question. No section could be found showing the relation of the schists to the surrounding limestones, as thick cotton soil covers all the margin of the schist area. It is therefore doubtful to what age to assign them. It is not impossible but that the schists are a protruding mass of the gneiss simply surrounded by the overlying limestone; but it might also be that these schists are merely highly altered shales belonging to the Lower Kaládgi series. The quartz veins which offer no peculiarities worthy of note extend a little further west-north-west among the limestones south-east of Hoskatti, and are finally lost under the great covering of cotton soil. Another set of rather irregular veins with a course east 5° north—west 5° south occurs among the limestone spreads south-west of Hoskatti (Lokapur synclinal valley).

B. Upper Kaládgi Series.

Synclinal ellipses.

Resting conformably on the lower series come the quartzites and overlying limestones, clay rocks and shaley beds forming the Upper Kaládgi series and occupying a number of small basins which form elliptical synclinal valleys, as the Shimakeri, Anathilli, and Lokapur valleys, and several others which form imperfect ellipses, the most important of these being the Arrakeri valley north of Kaládgi, and the Yenktapur valley north of Yádwád. Nearly all the outliers of these quartzites will be seen to be the remains of former synclinal foldings. The long westerly extension of the south side of the Arrakeri synclinal is also a remarkable feature in this part of the country because of its many sharp curves. A few small outcrops form inliers in the Deccan trap area within the limits of the Mudhol State.

Though properly divisible into two sub-groups as shown in the table of the Kaládgi series at page 71, the two sub-groups may preferably be considered together.

The quartzites are very uniform in character throughout, and may therefore be dismissed with but a brief description. As a rule, they are pale-colored and frequently conglomeratic, while local patches of brecciation are by no means rare, and occur almost invariably where the strata are much flexed.

The upper quartzites.

A glance at the map will show that a strong degree of parallelism exists between the axes of the several synclinal basins showing that they owe their origin to a set of great foldings formed by forces acting mainly in the direction of north-by-east to south-by-west. The parallelism holds good also to a great extent with the principal foldings of the underlying Lower Kaládgi rocks; the lateral pressure evidently, therefore, supervened towards the end of the period of deposition of the whole system, or was due to the upheaving action by which the Kaládgi basin was converted into dry land. This great upheaving, and a subsequent prolonged period during which the rocks underwent an immense amount of erosion, had evidently taken place prior to the outpouring of any of the local trap-flows, as is distinctly to be seen from the position the trap occupies in the eastern part of the Arrakeri synclinal valley and along the north side of the Jembigi ridge.

Axes of the synclinals all parallel.

The relation of the synclinal basins to the underlying rocks is well illustrated by Sections 1, 2, and 3 in Plate VIII. The Upper Kaládgi series nowhere extends beyond the actual limits of the limestone basin, and the area it occupies is extremely small when compared to that of the lower series.

Geographical limits.

Of the several basins which the upper series forms, that of Anathilli is the most instructive, although the smallest, because its form and area may be taken in at one *coup d'œil;* while the others, *i. e.,* Shimakeri, Lokapur, and Yenktapur, are too extended to be comprehended except by study from several points.

It will be observed that all the basins and ridges formed by the upper series are broken through by small streams flowing northward into the Ghatprabha. From the great height to which the upper quartzite outcrop ridges rise above the surrounding country, it becomes evident that the valleys must have been formed when the denuding forces had not as yet cut so deeply into the lower limestone series and formed the longitudinal valleys now running parallel with the quartzite ridges. The hardness of the quartzite is such that the drainage would not have taken place transversely across them unless lines of weakness had occurred here and there. Such lines of weakness were in some cases certainly due to comminution of the rock by excessive jointing.

Drainage along lines of weakness.

In the case of the nullah draining the Anathilli basin, this weakness of the quartzites along their southern wall is abundantly evident. A close examination of the lines of jointing there prevalent showed them to belong to the following systems, which are either wanting on the ridges east and west of the depression through which the stream in question flows or much less developed than in the intervening valley. Three systems of jointing are especially marked; they are—1*stly*, a joint running north 5° east to south 5° west, with an average dip of 45° west by north; 2*ndly*, a joint striking north 15°—17° east to south 15°—17° west, and dipping 55° east by south; and 3*rdly*, a joint striking north-north-west to south-south-east, with a dip of 30° west-south-west. The joint fissures are mostly close together, so that the rock is cut up into small fragments which can offer no great resistance to a rush of water. The brecciation of the quartzites at the apices of sharp flexures is in part due to ordinary systems of jointing, and in part also to systems of cleavage planes, but irregular conchoidal fracture is observable as well in numerous fragments.

Weakness due to excessive jointing.

The largest of the synclinal basins may well be called the Shimakeri basin after the village of that name, which is the largest place standing within its limits. The

Shimakeri basin.

basin measures sixteen miles by two and a half, and is, except at its south-western extremity, a simple synclinal ellipse, but at that corner the quartzites, instead of forming a simple ridge as they do elsewhere around the basin, one other spot excepted, roll over and form a small elliptical basin of no great depth—a large dimple, as it were, on the edge of the larger basin. The other spot is a yet smaller synclinal dimple, as it were, formed by the curling up of the edges of a small lappet-like extension of the quartzites on the south side of the basin immediately east of the new Sholapoor road. In both cases the rolling of the strata gives rise to a small knot of hills. The best sections of the upper quartzites in this basin are those of Mutikundeh (Mooteekundee), on the south and of Shiageri (Sheeagerree) and Truchigeri (Troocheegeree) on the north side of the basin in the gorges cut by different nullahs draining the basin and the country to the south of it. They offer nothing of special interest.

Lokapur basin.

The Lokapur basin offers an interesting section of the quartzites in the gorge by which the Lokapur nullah enters the basin from the south. The connection of this section with the capital limestone section seen in the same nullah near Warratsgal (page 125) is unfortunately masked by a small local spread of alluvium and the thick talus formed by the decomposing quartzites. The section in descending order is—

3. Breccia of quartzite.
2. Calcareous shales with limestones (? local).
1. Quartzites with some pebbly beds.

Talus hiding calcareous shales.

Red jaspideous breccia.

The breccia is a remarkably beautiful rock consisting of small fragments of drab quartzite enclosed in a dense jaspideous red matrix. The limestones are purplish-grey and blue in color, and possibly only of local occurrence. The overlying beds of the upper shale and limestone series are not seen in connection with the quartzites. The beds are upturned at an angle of from 75° to 80°. The basin is surrounded on all sides by a ridge of hills formed

by the outcrop of the quartzite series; but the north-western part of this ridge has been omitted in Atlas Sheet 41.

Arrakeri synclinal.

The southern side of the Arrakeri synclinal valley shows a very clear and well-marked case of inversion of the beds. The beds exposed at the Baulatti (?) (Bowluttee) curve have a dip of only 25 to 30°, but almost immediately they have trended round westward they become vertical, and at little more than a mile from the curve they lean forward to the north, so much as to present the appearance of having a true dip of 85° south. This continues past Kundurgi westward for some distance, when the beds again assume a vertical position and gradually return to a normal northerly dip, but at very high angles, which they maintain for several miles. These highly elevated and inverted beds show a great deal of brecciation. They are also in many parts conglomeratic in character, containing pebbles of quartz, jasper, and occasionally of older quartzite. In one conglomerate bed seen east of the Sholapur-Kaládgi road on the north wall of the synclinal, small sub-angular fragments of transparent green quartz, very like pale bottle-glass in appearance, occur pretty numerously, but only over a very small area. No such quartz was noticed in any of the gneissic rocks of that region. The matrix is a brownish-purple, gritty conglomerate overlying the bed which locally forms the crest of the ridge.

Green quartz in conglomerate.

Remarkable breccias.

The most remarkable show of brecciation which occurs in the upper quartzites is probably that seen at the great curve the quartzites of the Jembigi ridge make immediately east of the village of Chichgundi in the Mudhol State. Much of the breccia has a red, ferruginous, silicious matrix, and forms a very beautiful rock. North-east of Antapur the quartzites are also much brecciated, and the matrix being very hæmatitic, the breccia strongly resembles the chocolate breccia so typically displayed in the Lower Kaládgi quartzite series near the junction of the Ghatprabha and Krishna.

Great brecciation occurs also at the apex of the Wajarmatti curve of the upper quartzites and also close to Kalâdgi, at the western end of the "Cromlech hill" outlier. At most of the curves at the ends of the several synclinals the bedding is greatly broken up by jointing, *e. g.*, at Govindakop, at the north-west end of the Shimageri basin, at the east end of the Lokapur basin, at the western end of Anathilli basin, at the Baulatti (?) (Bowluttee) curve, at the east end of the Arrakeri valley, at the northern end of the sigmoid curve, north of Wajarmatti, and at the western end of the Yenktapur basin (the most westerly exposure of the upper quartzites). This great comminution of the bed surfaces is due mainly to the presence of rude cleavage joints caused by great pressure when the rocks were forced into the folds they are now seen to form. At the northern end of the Wajarmatti sigmoid these cleavage

Radial cleavage.

joints occupy a position distinctly radial from the western focus of the imperfect ellipse formed by the quartzite ridge. The surface of many of the curved beds is so greatly obscured by detritus that it is almost impossible to trace the actual curving of the lines of deposition; the comminution of the rock has gone to such an extent that it is generally very hard to find a mass of stone sufficiently large to be certain of its being *in situ*. The western end of the Jembigi ridge curves on itself and forms an imperfect basin which is entirely covered in by the Deccan trap.

The northern arm of the Arrakeri synclinal extends in a broken ridge

Arrakeri north ridge.

forming numerous inliers in the Deccan trap area for twenty-seven miles, nearly all across the northern part of the Mudhol State. The inliers mostly form narrow ridges 50 to 60 feet high, consisting of whitish or pale-reddish quartzite with pebble beds. One of the reddish beds occurring at Mahalingpur (Malingapoor) is very strongly rippled. The dip of the ridge declines steadily westward from 70° south, where it is crossed by the Sholapur-Bijapur road to 50°—60° at Arrakeri village, and 35° in the rippled bed on which the Mahalingpur fort is built.

The calcareous series resting upon the upper quartzites consists almost entirely of calcareous shales, purplish or grey in color, and overlaid by purplish and grey argillaceous shales; limestones only show occasionally and generally in thin bands. In some parts the purple shales are highly ferruginous, being richly charged with earthy red hæmatite. As a rule, the surface of this series is thickly covered by cotton soil, or by thick, red, ferruginous, gravelly soil (quasi-lateritic gravel) formed by decay of the hæmatitic shales. Large patches of this red soil occupy various parts of the Shimageri basin.

Upper limestones and shales.

The limestones occur more frequently or are accidentally more exposed in the western parts, where they lie at the base of the series, *e. g.*, at Murgur, near the western end of the Jembigi ridge and in the Yenktapur basin, and also in the Lokapur basin overlying the red jaspideous breccia in the section made by the Warratsgal nullah in the southern boundary ridge. They are grey, white, or bluish in color, and strikingly like the lower limestones occurring immediately south of the quartzite ridge at Lingapur.

At Murgur.

In the Arrakeri valley no distinct beds of limestone were observed, but there is a great thickness of calcareous shales of purple or grey color, with occasional laminæ of limestone. On these rest shaley beds of the same colors, which show very imperfect slaty cleavage parallel to the axis of the synclinal.

In the Anathilli basin calcareous shales only were noted. Among them are various very thin beds of rippled shaley quartzite. These occupy the central part of the basin. The beds resting immediately on the upper quartzites are concealed by superficial deposits, detritus or cotton soil.

No limestones were observed in the Shimageri basin, probably because masked by great spreads of cotton soil and by the red soil above

referred to. In the Gaddankeri (Guddengerree) nullah to the south of Shimageri village, grey and drab calcareous shales are seen, which extend southward up to the quartzites on which they rest. These shales are much but very irregularly cleaved parallel to the strike of the synclinal axis. The planes of cleavage are nearly vertical, but dip invariably north or south.

In a rock section at Shimageri a grey clay rock with silvery talcose surfaces occurs, and probably overlies the calcareous shales. East of Shimageri a large area is covered by purple ferruginous shales, with which occurs a bed of very rich hæmatite sandstone quartzite of dark-purple color. The section is obscure, but this ferruginous bed most likely belongs to the upper quartzites which have been brought to the surface by a small local anticlinal curve. Similar beds, but much poorer in iron, occur in two or three places in the small synclinal valley at the south-west corner of the basin mentioned at page 132. Hæmatite occurs also in the shales in the western corner of the basin, and has been smelted to a small extent. Traces of rich hæmatite beds were also noticed on the south side of the Arrakeri synclinal just east of the high road to Sholapur, and also in the bay formed by the Jembigi ridge south-east of Hira (Heera) Chichgundi in Mudhol State.

Hæmatite sandstones in Shimageri basin.

Calcareous and argillaceous shales only were observed in the Lokapur basin.

Intrusive rocks in the Upper Kaládgi series.

The only intrusive rocks occurring within the Kaládgi basin are trap dykes, which are very sparingly distributed, and occur only in the upper part of the series.

The trap dykes are three in number in the Lokapur basin, and one in the Arrakeri synclinal valley. They all consist of compact green diorite weathering in concentric

Dykes in Lokapur basin.

ellipsoidal masses, unlike any of the older diorites seen in the gneissic area. Their course is north-west-by-west to south-east-by-east, and they show only in the centre of the valleys among the shales.

In the absence of organic remains in the Kaládgi series, and from the geographically isolated position of the basin it occupies, it is impossible to correlate it closely with any of the other series rich in quartzites which occupy such large areas in Central India and on the eastern side of the Peninsula. The general resemblance in petrographical characters to the Kadapa series has already been mentioned above; but it remains to be pointed out that the Kaládgi series also shows in many respects a strong petrographical resemblance to the Gwalior (or Bijawur) series of Central India, which formation Mr. King in his report on the "Kadapa and Karnul formations"* has already assumed as the probable equivalent of the "Cheyair group," a well-marked sub-division of the Kadapa series. Unlike the Kadapa and Gwalior series, the Kaládgi formation contains no contemporaneous traps.

The "peculiar bed" of limestone with silicious bands overlying the Par quartzites described by Mr. C. A. Hacket in his paper on the "country near Gwalior"† appears to offer a very close resemblance to the non-brecciated parts of the silicious limestones occurring locally in the Lower Kaládgi quartzites to the north-west of Manoli (see p. 111), and to various highly silicious beds in different parts of the Lower Kaládgi limestones proper, in some of which—as, for example, that to the south of Kaládgi at Yendikeri—the chert bands assume the appearance of typical quartzites, which again pass into a distinctly oolitic silicious rock strongly resembling the oolitic silicious bands occurring in the Poolumpett group of the Kadapa series at Subrajpur (Soobrajpoor), three miles north-west of Rayalchera station on the north-west line of the Madras Railway.

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* Memoirs of the Geological Survey of India, Vol. VIII, p. 291.

† Records of the Geological Survey of India, Vol. III, p. 35.

A very strong resemblance must also be noted between the ferruginous ribboned jasper and hornstone beds of the Morar group in the Gwaliors and the jaspery hæmatite schists occurring in the Lower Kaládgi series west of Bilgi. Some of the hornstone (jaspideous quartzite) breccias, as well as other rocks from both regions, are strikingly alike when judged by hand specimens.

CHAPTER V.

THE BHIMA (KARNUL) SERIES.

Some eight miles to the eastward of the extreme north-east corner of the Kaládgi basin commences another series of sub-metamorphic rocks differing considerably in petrological character from the Kaládgi series, and resembling very closely in many respects the Karnul series, the younger of the two sub-metamorphic series occupying so large a tract on the eastern side of the Peninsula. The older series, or Kadapa series, on the contrary, as already mentioned, strongly resembles the Kaládgi series just described. To the younger series in the Bhima and Krishna valleys the very suitable name of Bhima series has been given by my colleague Mr. King.

As no recognised members of either the Kaládgi or Bhima series have been met with in contact, and therefore no stratigraphical evidence exists to assist in determining their identity or difference, that determination has had to be made entirely on the grounds of petrological dissimilarity, which is very marked. This determination is strengthened by the analogy of the two groups on the eastern side of the Peninsula, between which a very clear and great break has been shown to exist.

The four sections given on Plate IX illustrate very well the structure of the western and eastern parts of the basin occupied by the Bhima series. The central part is much more complex and will be separately illustrated.

The series may be divided into two divisions, upper and lower, with the following sub-divisions, a full list of which will be found further on :—

B.—Upper Bhima series.

g. Red shales.
f. Flaggy limestones.
e. Buff shales.
d. Quartzites (local ?)
c. Limestones—" Talikot" beds.

A.—Lower Bhima series.

b. Red, purple, and green shales and shaley sandstones.

a. Quartzites, grits, and sandstones.

A.—The Lower Bhima series.

In the western part of the Bhima area the sandstones and shaley sandstones show a considerable variation in color, from white to red, purple or green, with endless intermediate shades. As a rule, the reddish-brown and purple tints prevail near the upper part of the formation, followed by drab and greenish beds, whilst near the base yellowish-green or brown and dirty-grey tints predominate.

The total average thickness of these arenaceous beds amounts probably to about 100 feet, and they may be best studied along the eastern

Section of Tirth plateau.

and northern sides of the singular peninsula-like plateau of Tirth (Teertu) (see map and section, Plate IX). At the eastern extremity of the plateau they are perfectly well exposed in a very clear natural section on the bare hill side, and the above enumerated succession of tints is traceable even from some little distance. The colors, however, are not sufficiently constant in their distribution to afford a perfectly safe guide as to the relative position of outlying pieces of this sandstone and shale series.

Some of the sandstones are deserving of a little notice, especially

Jambaldinni sandstone.

one bed of a purple gritty sandstone which occurs at Jambaldinni (Jumbuldenee), a village in the Muddebihal Taluq, seven miles from Muddebihal and seven and a half from Talikot. This bed is largely quarried by the Waddras* for hand millstones of a superior quality. The bed is very unusually massive for the Karnul series in this region, the partings of the sandstone being from 2′—3′ or more apart. Besides the purple color, which is very decided, this sandstone is characterised by containing a number of bright green grains of small size.

* A wandering tribe of quarrymen, masons, and tank-diggers found all over Southern India.

A precisely similar purple gritty bed occurs at Bulehwar, five miles north-west of Jambaldinni; this probably occupies the same horizon in the Karnul series as the Jambaldinni bed. But five miles to the south-south-west of Jambaldinni at Kaurimatti (Kowreemuttee) a similar purple gritty sandstone forms the base of the Karnul series.

About two and a half miles south-east of Jambaldinni a bed of purple gritty sandstone (almost a quartzite in texture where not excessively weathered) caps a table-topped hill with a well-defined scarp (not laid down in the map). This is probably the same bed as the Jambaldinni millstones are quarried from. The south side of this small table-land is well scarped, and shows a total thickness of about 100 feet of Lower Bhima rocks, arranged thus:—

Jukrihal hill section.

3. Purple, gritty sandstone (quartzite).
2. Drab, olive and purple and dark-green shaley sandstones.
1. White or drab pebbly grit.

Gneiss.

The shaley sandstones form more than half the thickness of the whole section. Much pisolitic laterite gravel occurs, strewn over the surface of the purple sandstone.

A purple gritty bed, occurring near the base of the series, is quarried at Bassarkot (Bussurkee), five miles north-west of Muddebihal. This bed is quarried for millstones.

The basement beds of the Bhima series in the western part of the area consist almost everywhere of pebbly or gritty sandstones of moderate thickness rarely exceeding from 30 to 50 feet, and resting directly on the highly uneven surface of the gneiss, which in many places stand up in great hummocks, surrounded by the younger deposits. These may in several places be seen protruding far above the base of the younger series, *e. g.*, at Salwargi and Matkaldevunuhal on the Talikot-Sorapur road, where, as shown in Section III, plate IX, the granite gneiss rises in three or

Mineral characters of basement beds.

four large hummocks upwards of 100 feet high from among the shaley sandstones, and actually towers over the surface of the limestone plateau close by.

The pebbly character of the basement beds shows them to have been deposited in shallow water around the base of the low gneiss hills, which probably formed islands in the sea which deposited the lower part of the Bhima series. The materials of which these pebbly conglomerates were formed were evidently derived from the degradation of the adjacent gneiss; and this rock yielded the quartz and red felspar crystals which make up the mass of the pebble beds. As the sea bed sank, the character of the deposit changed till it attained the deep-sea character of the Talikot limestone.

As before mentioned, the basement bed is sometimes a gritty sandstone instead of a pebbly conglomerate, but the latter character is, on the whole, predominant, as might be expected.

Prevalent colors.

The prevalent color of the conglomerate beds is a pale-brown, the matrix being generally of a lighter color than the included quartz and felspar fragments. A pinkish or reddish-brown color is, however, far from uncommon in the conglomerate beds from the great quantity of comminuted red felspar they contain. White and purplish colors are also met with locally.

Rippling in quartzite.

Some of the sandstones are rippled, and occasionally approximate in closeness of texture to true quartzites. Such is the case in a white sandstone bed resting on the very thin white pebbly conglomerate about a mile south-east-by-south of the Nagurbetta hill, also in a brown sandstone occurring just within the Agani (Uguni) valley close to the village of Kusukunahal (eleven miles west of Sorapur). Here in parts of the bed the stone has the peculiar waxy lustre so characteristic of

Kusukunahal conglomerate.

typical quartzites, whilst a few yards off it can only be considered as a fine close-grained sandstone. This bed is only 4 or 5 feet above the gneiss. The actual basement bed at this place is a brown pebbly conglomerate with rolled pebbles of quartz and gneiss. Amongst these, I discovered what appeared to be a rolled fragment of silicified wood (or bone ?) which was the only indication of anything organic obtained from any member of the Bhima series.

Schistose flagstone.

An unusual form of sandstone resting on the thin basement pebble bed occurs between Tirth and Bazuna Kolur along the southern edge of the Tirth plateau. This sandstone has a quasi-schistose lamination, and separates into very rude-looking flags. Much of this is due to the diagonal bedding on a small scale, which is very frequent among the composing laminæ of the rock. This sandstone has been used in the construction of a remarkably fine group of dolmens standing about half a mile west of Bazuna Kolur. The top slab of one of these was measured roughly; its dimensions were rather more than 11 feet by 8, with a thickness of from 10″—14″ or thereabout.

Dolmens.

Owing to the great amount of talus accumulated along the foot of the scarp forming the west side of the great Uguni valley, the lower part of the Bhima series is hardly anywhere to be seen between Yeddihalli and Fathipur (?) (Futtipoor).

At Kembhawi the basement bed is a brown pebbly conglomerate filling a shallow bay in the gneiss rocks, but northward and eastward of that place the basement sandstones and shales die out completely, and do not reappear along the southern boundary of the Bhima basin till eastward of the Bhima river. At Bachimalli, the extreme easterly extension of the Bhima rocks in this region, the basement is a pebble bed, drab and pinkish-white in color. The surface of this bed, which strongly resembles some of the diamond beds of the Lower Krishna valley, is much broken up by

Basement bed at Bachimalli.

small pits, but I could not learn after much enquiry that diamonds had ever been sought for or found in this region.*

Bhairapur hill.

The sandstones forming the hill, at the east end of which stands the village of Hala (?) Bhairapur (old Bhyrapoor), are drab in color, the basement bed being a pebbly conglomerate.

South of this hill at Manzilpur, and away to the south-west of that village, the pebbly character of the basement bed is very strongly developed. The enclosed red felspar crystals are here so little rounded that the beds assume more of the character of a breccia than a conglomerate.

South of Tirth the pebbly character is again well seen; further westward towards Kodekal and Bodihal the rock is generally a gritty reddish-brown sandstone, but it again assumes the pebbly character near the Don river.

Basement beds west of the Don.

West of that river, along the south side of the long spit of sandstones which extends eastward of the road running from Nalutwar to Talikot, the pebbly basement bed is everywhere distinctly traceable, and is overlaid by beds of gritty and fine sandstones of a brown or reddish color.

Near the village of Kuriakanuhal, the conglomerate is purple in color, with very numerous included broken crystals of red felspar, the whole forming a remarkably handsome stone.

A similar purple pudding-stone occurs again at Hokarani (Hokaranee), two miles southward of Jambaldinni. This purple color recurs in the gritty sandstone at Kaurimatti already referred to. The pebbly character of the basement beds now becomes less marked, and

* The old French traveller Tavernier mentions the occurrence of diamond mines near Bijapur, but I have been unable to see a copy of his travels in order to ascertain any particulars regarding the mines mentioned.

only gritty sandstones with fine sandstones resting on them are commonly seen at Muddebihal and to the north-westward of it, but there is nowhere a total absence of the pebbly conglomerate, which may be traced in each of the several patches of Bhima rocks up to Alkopur.

This feature is also observable in the Balwantarkatti valley north of Muddebihal. The beds show many signs of slight disturbance prior to the outpouring of the Deccan trap-flows, being frequently a little broken and upturned, whilst they roll about in all directions, generally at low angles.

The sandstones between Kaurimatti and Muddebihal are of drab and pale-brown color; those forming the outlier which caps the Sirur (Suroor) hill are white, drab, and purplish, the white beds being rather unusually massive and compact, but showing many small, shallow, conchoidal cavities, as if compressed clay-galls had been weathered out. The beds are here quite horizontal. At Muddebihal and thence north-westward along the valley of the Bágewári nullah the prevalent color of the sandstones is a pale reddish-brown weathering to a cinnamon-brown. One noteworthy exception to this is a remarkably white sandstone, very saccharoid in appearance, which occurs at the extreme south-west corner of the Muddebihal plateau. As already mentioned, the sandstone immediately underlying the limestone is absent in that part of the Bhima formation which lies east of the Don river, or else it is so thin as to deserve no special notice; otherwise much the same characters are exhibited by the shaley sandstones forming the middle sub-division of the Bhima rocks east of the Don river.

White saccharoid sandstone near Muddebihal.

The excellent section at the east end of the Tirth plateau has already been described (page 140), but there are many other spots where the shales and shaley sandstone beds are well displayed, *e. g.*, between Muskanhal and Bilibhávi south-east of Talikot and around Malanur on the road from Talikot to Sorapur, where the purple color predominates near the base of the series. In the small outlying hill a mile and a half to the south

Lower or purple shale series.

of Malanur a thin set of transition beds between the base of the limestone and the shaley sandstones is well seen near the top of the hill, while further down the alternation of drab and green laminæ is very well marked.

Still further east, along the Talikot-Sorapur road the purple shaley beds are largely seen between the villages of Kaludevunuhal and Hebbal Buzruk, where the small river cuts deeply into them, forming cliffs 30 feet in height and upwards.

The shaley sandstones may also be well seen nearly everywhere along the scarp which sweeps round the south and west sides of the Agani (Uguni) valley, along which they present no characters sufficiently different from those before given to merit separate mention.

In the small Kembhávi outlier they re-appear with the highly characteristic purple color, but with the basement sandstones they die out here and are not seen again till east of the Bhima.

Eastern parts of the Bhima basin.

In the eastern part of the Bhima basin, the basement series of conglomerates and grits was found by Mr. King to have thinned out very remarkably, and to be represented only by a thin-bedded quartzite or semi-vitreous pebbly sandstone from 6 inches to 2 feet thick only. It may be seen between Nalwar station (Great Indian Peninsula Railway) and Purdapalli (Poordapully), occurring as a mere skin filling up hollows in the gneissic rocks. Further north, where forming a continuous bed underlying the purple limestones and shales on which the village of Nalwar stands, this basement bed is only from 4 to 6 inches thick. This sandstone shows strongly at the base of the conspicuous conical hill called Kudapur Qubur, and also up the western slope of the Sunkanur (Soonkanoor) plateau.

Sunkanur plateau.

The sandstone is mainly made up of little quartz pebbles about the size of boiled rice grains, and all of more or less transparent quartz. The cementing material

is in part ferruginous, in part a green earthy substance. Some beds of sandstone contain, in addition to the quartz pebbles, angular fragments of red felspar of moderate size. In weathered masses the small "rice-grain" pebbles of quartz acquire a dull white color, and look not at all unlike lumps of boiled rice. These sandstones are not continuous round the scarped slope of the Sunkanur plateau, but appear at intervals. They follow the undulations of the gneiss surface.

"Rice-grain" grit.

The sandstones on the plateau are regularly overlaid by fine greenish sandstone and sandy flags, and slightly micaceous shales; the shales are merely local. A much better display of these sandstones and shales is to be seen on the Kudapur Qubur (of map) or Lalapur hill already referred to. Here Mr. King found at the base a thin series, one to three feet thick, of coarse, pebbly sandstones and grit, full of little rounded pebbles of clear quartz and with felspathic fragments. The cementing materials here also are occasionally of a green color.

Lalapur hill section.

Over the grits come about 30 feet of dirty green and greenish-brown fine shales and flags, the lowest beds being rather more compact and fine-grained with associated bands of more massive and concretionary rock. Then over these come in gradually chocolate and red-purple shales with seams of limestone, and higher-lying calcareous flags forming the summit of the hill. There are about 80 feet of purple beds on the shales, and this would give 110 feet of dingy green and purple shales before the true flags of the summit are reached. Excepting in the thinness of the basement sandstones, this section agrees closely with the sections of the corresponding beds in the northern and eastern flanks of the Tirth plateau to the south-east of Talikot, which sections may be fairly called the typical ones for the western part of the Bhima basin.

Green shales.

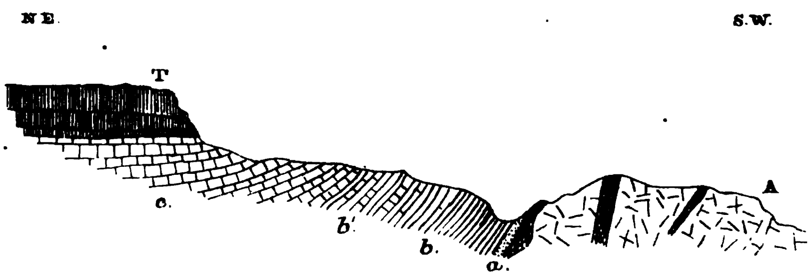
Purple shales.

Other sections, both southward and eastward, show these purple-red shales apparently graduating upwards into a series of limestones, which

are largely developed in the valleys of the Bhima and its eastern tributary, the Kogni, and which clearly answer to the Talikot limestones of the western part of the Bhima basin. A well-marked and extensive overlap of these limestones on to the gneissic rocks along the southern boundary of the basin between Kembhávi and Gogi shows, however, that a break in time must have taken place between the deposition of the calcareous shales and the Talikot limestones, or that there must have been a change in the depth of the sea (or lake) in which the Bhima rocks were formed, of so great and rapid a character as to indicate the necessity of regarding the two sets of rocks as quite distinct members of the Bhima series.

The same succession of beds as that above given is found to be constant to the southward as far as Rampur on the left bank of the Bhima, and eastward as far as Bimanhalli (Beemunhully), a distance of eleven miles from Lalapur hill. The beds lie undisturbed all along this curved boundary line as far as Halhalli (Halhully), five and a half miles to the north-east-by-east of Lalapur hill, where they begin to dip northward at high angles. At Allur (Ulloor), three miles further east, the beds are crushed up vertically against the gneiss as shown in the following section :—

Allur section.



Section through Allur hill :—T. Deccan trap. c. Limestone. b. Calcareous shales. b1. Purple shales. a. Basement grit. A. Gneiss, &c.

Mr. King describes this section as follows :—" At the point of section the bottom beds of grit and sandstone, very thin, are lying up against a nondescript quartzo-felspathic rock, much 'stringed' with

red granite, and also traversed by greenstone. There are no indications of alteration along the junction, except what might have been brought about by crushing, which most certainly took place, for the beds were never deposited as they now lie. The line of junction or faulting runs about north-west to south-east, with a dip to the north-east of from 40° to 60°."

Abnormal gneiss.

The nondescript quartzo-felspathic rock is very different from the usual gneiss of the country; it shows no regular structure, but has its constituents strangely mixed up together. It may be igneous, and it certainly appears to be such, but its present form and constitution may also be the result of violent crushing and of the intrusion of granite and trap. To the east, west, and south the country is so covered up by superficial deposits that it is difficult to say how much further the dislocation or igneous action extended. There does not appear to be any connexion between the trap traversing the nondescript rock and that capping the hill north of Allur. Traces of an extension of the line of dislocation appear in the gneissic rocks of the Kogni valley close to the Great Indian Peninsula Railway bridge. Mr. King points out further that the disturbance in question took place prior to the deposition of the Deccan trap.

The total thickness of Bhima rocks exposed in the Allur section measures about 120 feet, of which 84 are shales.

B—The Upper Bhima Series.

At Talikot.

The lowest and by far the most important sub-division of the Upper Bhima series includes the Talikot limestones (*c*) which are largely exposed at and around the town of Talikot in the western part of the Bhima area, and still more extensively in the eastern part of the area along the Bhima and its tributary the Kogni. The limestone is mostly of a kind which has been

called "lithographic" limestone, a very fine grained, dense, waxy-lustred variety, with decidedly conchoidal fracture. It occurs in flaggy beds, the individual flags having a thickness of from 3 to 6 or 8 inches. They are very easily quarried, and are used exclusively as the building material of the neighbourhood,* besides being largely carried away to considerable distances for better-class building of all kinds. In a few places the beds are massive, from 2 to 3 feet thick, and do not separate into flags.

Prevalent colors.

In color there is great variation, the general succession of color from top to bottom being bluish-grey, grey, drab or cream-colored, pinkish, and purplish; the latter variety resting usually on purple shaley sandstone. This scale of color does not, however, hold good everywhere, and in some localities the basement of the limestone series is of grey color.

Thickness observed.

The total thickness of the limestone near Talikot may be estimated at about 80 feet. This estimate was made at the edge of the limestone area near Salwárgi, six miles east-south-east of Talikot, where the almost universal covering of regur is absent. Further to the north-east, however, at Gogi, Mr. King found younger beds of limestone, which had been left undenuded, and the greatest thickness of the limestone far exceeds the above estimate.

Lie of beds.

The limestone all around its boundary as far east as Kembhávi (south-west quarter sheet 57) dips inward generally at a low angle (a few exceptional cases will be mentioned further on), and within the area the beds most frequently roll about in all directions, but always at low angles. The inclination very rarely exceeds from 2° to 5°.

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* The town of Talikot is chiefly built of the drab and cream-colored varieties, which present an extremely handsome appearance and are locally most esteemed.

The limestone is directly overlaid by the trap-flows, but I did not see a single section in which the contact of the two formations was well exposed, so I could not ascertain to what extent the metamorphic action of the trappean heat may have extended. Such points of contact were, however, observed by Mr. King, and are thus described by him: "West of Tengalli (Tengully), on the Bennathora river, twenty miles east-south-east of Gulbarga, there is a long spur-plateau of compact grey basaltic trap with olivine, capping limestones and clayey calcareous shales which appear to be reddened to the depth of a foot or so, but below that are grey or purplish and earthy.

Effects of heat of trap-flows on the Bhima rocks.

"Again, in the outlier some five miles north of Tengalli (Tengully), the same flow overlies much more compact and splintery beds of fawn-colored limestone, which in some places have assumed a white color and a more crystalline texture when in contact with the overlying trap."

Other cases of similar character in higher-lying limestones and shales will be mentioned further on.

Small "sinkings in" of the limestone at the surface are very commonly to be met with; these are apparently due to the action of springs which have dissolved away part of the underlying mass and then caused the overlying parts to fall in. These "sinkings in" affect the apparent position of the limestone frequently, but only over very limited areas, and are, as a rule, easily distinguished from cases of normal dip.

Sinking down of limestone surfaces.

The limestone beds have been much wasted by the indirect action of the weathering agencies, which have worn away the underlying soft shaley sandstone to a very much larger degree than the hard compact limestone capping it. Great masses of the limestone have been thrown down and broken up, and remain in many places in the form of a talus at the foot of the limestone and shaley sandstone scarps, and furnish the principal

Landslips due to more rapid weathering of the shales.

material for the formation of the remarkable tufa-cemented breccias and conglomerates mentioned at various places.

Landslips.

Two remarkable instances were observed of large fallen masses of the capping limestone, which, though much broken up, distinctly show by their position and present condition that they must have sunk down *in situ* as the soft shaley sandstones were gradually removed from under them. Both these examples occur in the Agani (Uguni) valley to the north-west-by-west of Sorapur. The first and most important in size occurs about two miles south-east of Agani. It occurs in the form of a low hillock 80 to 100 feet in height, and about three quarters of a mile in length. In width it tapers from about 300 yards at the west end to a mere point, dying away under the regur at the east end. This hillock is very bare of vegetation, and is seen to consist of nothing but broken limestone fragments, among which it is possible here and there to distinguish traces of the bedding formerly existing, but the general mass of broken slabs is in a state of perfect confusion. At the west end the limestone rests apparently on granitoid gneiss; the actual contact is not exposed, but the two rocks occur *in situ* within a few feet of one another. If, as there is every reason to believe, this limestone was once continuous with the main plateau occurring beyond the little hamlet of Sadab (Sudub), about three-fourths of a mile to the west, the amount of shaley sandstone removed from below the limestone must have been fully 60 to 70 feet in thickness. The usual basement bed of the Bhima series, a pebble conglomerate, generally a hard and compact rock, was probably of a softer character than usual at this spot, and therefore removed by weathering, together with the friable shaley sandstones, and thus the limestone rests now directly on the gneiss. At the nearest spot at which the basement of the series is seen (namely, about a mile west of Yeddipalle and three miles south-east-by-east of this singular limestone hillock, which may be regarded as a "let-down" outlier), it consists of a soft drab sandstone with small shaley bands in it.

The second case of a "let-down" outlier of the limestone, though of much smaller extent, is perhaps of greater interest, as its origin is perfectly obvious at the first glance. It consists of a mass of limestone about an acre in extent, situated at the base of the limestone and shale scarp half-way between the villages of Sadab and Ugutirth (Uguteert). The limestone mass is of rudely triangular shape, and considerably upturned at the edges except on the east side; the centre being approximately horizontal. The sunken mass is round its edges so surrounded by the tufa-cemented limestone talus that it is not possible to see on what it rests, but it is probable that a thin remaining part of the shale beds underlies it and separates it from the gneissic beds. The surface of this mass is fully 40 feet below the position it must have occupied previously to the removal of the shaley sandstones which caused its subsidence.

Landslip on Lalapur hill.

Somewhat analogous to these cases is that of a landslip on one side of Lalapur hill, three miles north-north-east of the Nalwar railway station, described by Mr. King in his notes: "On the north side of this hill, near the base, there is a strange tumbled mass of limestone and shales; none of the limestone is now *in situ* on the hill, but it is the same as that seen in other parts of the country around overlying the purple and red shales. The tumbled mass of rocks is large, extending for about one-third up the side of the hill; junction not seen."

This hill seems once to have been of greater extent and height, in which case the summit would then have been made up of limestone beds, with perhaps a spur running out on the north side. The débris of this slide now remain at the base of the hill as a tumbled mass of purple shales, grey flags, and fawn-colored massive limestones. A great part of this mass is now an exceedingly coarse tufa-cemented breccia of broken fragments of limestone flags, and beds similar in character to the breccias above referred to, which will be found described in Chapter X. Mr. King thinks that this slip, which took place on the north side of the hill

since the country was denuded into its present shape, may have been induced to some extent by the presence of oblique planes of jointing, which are very strongly developed in the underlying shales.

Generally prevalent colors.

The general color of the limestones is grey, but, as already mentioned, other colors prevail locally, *e. g.*, at Maileshwar (Mylaishwar), two miles east of Talikot, drab and cream-colored limestone with bands of pink and purplish color is found covering a considerable area. The pale cream-colored variety is most valued locally as a building stone, and commands a higher price. This predilection seems to apply solely to the color, for the grey variety is of tougher and more durable character.

Cream-colored limestone at Channur;

Another locality where the pale drab and cream-colored limestone occurs is the rising ground south of Channur on the road between Talikot and Sorapur, and fourteen miles from the latter place. Several hundred acres of limestone are here exposed, and form a surface singularly bare of vegetation, the beds dipping north at an angle of from 2 to 3 degrees.

And at Agani.

To the west of the village of Agani (Ugani)* is a quarry in which cream-colored and drab waxy limestone is quarried to a large extent as building stone. Some beds here are also pinkish and purplish in color, as those found near to the village of Maileshwar above named, while a few are of a French grey tint.

Purple beds near the base.

Purple limestone occurs south of Maileshwar and also at Tirth along the southern edge of the singular peninsula-like extension of the limestone area south of Sálwárgi. In both cases the purple beds are close to the base of the limestone formation and rest upon purplish shaley sandstone.

* The quarry here referred to lies about a mile east of the boundary of the Kaládgi district, on the south side of the stream.

At Tirth the limestone, which generally lies horizontally or rolls about at low angles, is seen to be elevated to an angle of from 15° to 25° with a northerly dip. Eastward of Tirth this upheaval of the limestone soon disappears, but to the west it extends for several miles to the extremity of the limestone plateau south of Hagartungi (Hugurtungee). This high angle of dip (relatively speaking) does not extend more than a few yards inward from the basset edge of the limestone plateau, while to the south of it the underlying shaley sandstone beds soon resume a very low northerly dip or are horizontal. A similar increase of dip close to the basset edge of the limestone formation is to be seen along its southern boundary southward of Talikot. This may be traced for a distance of several miles from a point a little to the east of where the path between the villages of Bilibhávi (Beeleebhawi) and Maileshwar (Mylaishwar) crosses the limestone boundary westward to beyond the village of Kuchbál (Koochbal). The beds are tilted up at an angle of 45° to 50°, but further west the angle decreases gradually.

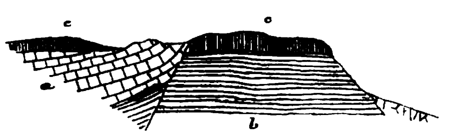
Section at Tirth.

Upturned basset along south boundary.

In both cases this local increase of dip seems due to a slight upthrow of the beds on the northern side of a line of fault.

In another case which occurs along the southern boundary of the limestone formation to the north-east of Sálwárgi the faulting of the beds is undoubted, for they are seen to abut against other and older rocks. This is seen about one and a half miles north-east-by-north of Malanur * and one and a quarter miles south-south-east of Kolihal. The limestone beds here abut against the overlying trap-flow as shown in the annexed diagram sketch. The faulting took place evidently at some period prior to the outpouring of

Fault near Sálwárgi.



Pre-trappean faulting. *a*, limestone. *b*, shales, sandstone, &c. *c*, trap.

* The first village in the Nizam's territory eastward of Talikot on the Sorapur road.

the trap-flows, as the limestone has been denuded away to the south of the fault, owing to which the trap there rests directly on the shaley sandstones. Close to the line of fault the limestone dips to the north at 40°, but in a very little distance (30 to 40 yards) the dip has decreased to 15°, and continues decreasing rapidly till the beds are all but horizontal. The shaley sandstone south of the fault lies horizontally. A couple of hundred yards north of the fault the trap rests on the limestone, which has not there been denuded. This fault seems not to extend westward beyond the head of the bay-shaped valley where it occurs, for the limestones on the west side of the bay rest on the shaley beds in undisturbed conformity. To the eastward the line of faulting extends several miles, but everything is covered by thick regur till beyond the villages of Dewapur and Katapur. About a mile to the eastward of the latter village, the limestone boundary is again seen protruding above the surface of the country and its dense covering of cotton soil. The dip of the basset edge is again northerly, and varies from 30°—35° near the crossing of the Talikot-Sorapur road, to 75°—85° south of Kalludunuballi. The same rapid decrease of dip to the northward is again observable here from 30° at the basset edge to 2° or 3° only a few score yards to the north. The limestone certainly appears to abut against the gneissic rocks, but the contact was not seen anywhere owing to the thick coating of superficial deposits just at the edge of the limestone area. The gneissic rocks are coarse-grained, and have weathered so greatly that no protrusions of them are seen anywhere near the limestone boundary. Eastward of the spot where the extremely high dip of the basset edge of the limestone before mentioned is met with, the fault can no longer be traced owing to the great continuity of surface deposits. It evidently dies away gradually, for between Hebbal Khurd (Khoord) and Bachimalli, where the boundary has again become uncovered, it is a boundary of erosion, not of faulting.

Except along the western side of the limestone basin from where the Bhima river enters it, and where the limestone series is overlaid by an upper series of red shales, the upper limestone beds, from near

Gulbarga eastward, are everywhere along the northern boundary of the basin, covered up by the Deccan trap. The unconformity between the two rock series is less distinct here than further north, but it can be traced in the shape of overlap on limestone beds occupying very different horizons. The highly disturbed and broken beds of limestone between Parwattabad and Deyrun Tegganur are also overlaid by level flows of trap.

Unconformity of trap and Bhima limestones.

West of the Bhima very nearly the whole area up to the scarp of the trap boundary north and north-west of Gogi is occupied by the limestones which mostly lie horizontally or roll about at low angles, except along the southern boundary of the basin, where their relations are much complicated by great disturbances of the strata, which are due both to faulting and crushing, as will be described in detail further on.

Disturbed and faulted boundary at Gogi.—For a distance of some twenty-five miles the boundary of the Bhima basin (to the south of the old town of Gogi) runs generally in an east to west direction, and, for the greater part of that distance, the lowest beds which there occur are seen in a vertical position abutting against the gneiss. The western end of this line is so obscured by superficial deposits that Mr. King found it very difficult to lay down any definite boundary between the gneissic rocks and the Bhima beds, but wherever he hit upon the limestone, it was vertical or at very high angles. Actual contact of the two rock series was not seen westward from Darshinapur* towards Veur (Veyoor), but near the latter place some blue thick-bedded limestones, vertically upraised, show extremely coarse breccia-structure, and enclose fragments of other limestones. They also contain beds of chert. There are here two bands of blue limestones enclosing thinner bands of grey silicious beds full of chert nodules and

Coarse limestone breccia.

* Three and a half miles west of Gogi.

strings. The beds at the boundary are, as a rule, vertical or nearly so, the dip being sometimes north, sometimes south (? by inversion).

South of Hukanahal (Hookunahal) six miles west-by-north of Gogi, are two low ridges in a line (faintly shown in the atlas sheet) consisting of these lower limestone beds with a vertical or very high dip. On the south side of the ridges is a thin band of the blue limestones; the ridge itself consists of the silicious beds, and a thicker band of blue limestones lies on the north side. Northward the upper red shales come in, but their relation to the limestone is not visible.

In this ridge the three bands of limestone are at least 600 feet in thickness. This vertical position of the lower beds continues on to Gogi, the dip of the higher beds decreasing from the boundary northward.

Quartzite series.

The Durga (or Mausoleum) west of Gogi stands on a thin group of compact and close-grained quartzites which appear between the blue limestones that lie at lower angles immediately below the Durga hill, and a considerable band of very fine buff shales (like the Auk (Owk) shales* of the Karnul series) which shows a little further to the north. This band of quartzites occurs in thick and thin beds dipping about 10° northward, and appears to be conformable to the limestones. At the south-west corner of Gogi town the quartzites are vertical, and to the east of the town they thicken out greatly, and upon a low ridge between the villages of Hulakal (Hoolukul) and Hottapatti, but finally disappear under the superficial deposits of the Madarki (Mudurki) nullah. From this quartzite and conglomerate ridge the whole overlying series may be traced up to the upper red shales.

South of the quartzite ridge just described occur the massive blue limestones, underlaid in their turn by thinner beds with cherty and

* Described by Mr. King, vol. VIII, p. 67.

silicious laminæ which form another well-marked but lower ridge, on which is built the Durga lying north-east of Gogi. The lower blue limestones appear below the silicious beds.

At Gogi the lower beds are vertical, but the dip decreases as they are followed eastward, while the cherty band of limestone seems to have thickened as well as the overlying quartzites, the former giving rise to the Durga ridge, the latter to the Hottapatti ridge above named; and, in each of these, the beds of which they are respectively made up must have a thickness of at least 200 feet.

Eastward of the Hottapatti ridge the limestone bands are traceable with a steadily decreasing dip to the neighbourhood of Bidderani, where the lower red shales with their underlying dirty green and brown associates show below the limestones.

Basement beds and red shales not present or hidden.

Nowhere along the Gogi boundary line were the shales or basement sandstones seen. In all probability they were not developed there: if they were, they must be so thin as to be very easily obscured, or else they must have been crushed or faulted out of sight.

The quartzites of the Hottapatti ridge appear to be only a local intercalation, though one of great importance and interest; they were not met with elsewhere.

Mr. King thinks the cherty silicious beds forming the Durga ridge may represent the similar beds on the hill west of the Shahabad railway station.

Although these different bands of limestone, quartzite or shale appear to be quite conformable, Mr. King thinks it is possible that the Hottapatti quartzites may represent a break between the compact blue limestone (and its underlying shales, &c.) and the upper flaggy and more earthy limestones with their overlying red shales.

Central part of the basin.

The succession of beds seen in the central part of the Bhima basin, as determined by Mr. King, appears to be as follows:—

BHIMA SERIES.	Upper.	*g.*	Red calcareous shales of Muduwal (Moodoowal) Buzruk	30′—40′ observed.
		f.	Flaggy limestone beds of Jewargi (Jeywurgi) or Madarki (Mudurki).	
		e.	Buff shales of Gogi	18′—20′ observed.
		d.	Quartzites (sandstone) and conglomerates of Hottapatti	200′—300′ observed.
		c.[2]	Blue thick-bedded splintery limestone brecciated in part	200′ observed.
		c.[1]	Thin-bedded and flaggy limestone with chert, &c., of the Eastern Durga, Gogi, and of Shahabad (?)	200′
		c.	Blue and grey splintery limestones with occasional breccia beds—"Shahabad" beds = Talikot beds ...	200
	Lower.	*b.*	Purple and red and dirty-green shales of Nalwar ...	110′
		a.	Thin-bedded "rice-grain" quartzites	6″—2′
			Gneiss.	

Only the three lowest of these groups are represented in the eastern and western parts of the Bhima basin, namely—

c.	Very compact "waxy" limestones, "Talikot" beds, grey, cream-colored, blue, purple, pink, &c., with some shaley beds; some beds are "lithographic"...	80′ observed.
b.	Purple, red, drab, and dark-green shales with thin calcareous flags or shales near the top. Locally a gritty purple quartzite underlies the limestone, especially in the most westerly sections ...	80′ 100′
a.	Quartzites, sandstones, and conglomerates ...	5′ 60′

Upper red shales.

On the north-western border where the Bhima river emerges from the trap area, Mr. King found the limestone series to be overlaid by an upper series of red and purple shales which form the highest known member of the Bhima series. It is quite possible, however, that yet higher or younger beds may be concealed under the overlying trap. These upper shales extend southward and westward under the trap. Mr. King describes them as hardly

distinguishable from the lower red shales, except that they are perhaps rather more earthy.

The dirty-green or brown mud shales are not represented in the upper series, which is also redder in color. Some of the higher beds are much brighter in color than the lower shales, being quite pink, and occasionally almost vermilion, where they have been affected by the overlying trap-flows. It seems very probable that the latter has been the case, for where the shales are of a bright red color in the immediate vicinity of the trap the bedding is very often obscure; indeed the red rock might almost be taken for a form of decomposed trap. This, however, it does not appear to be in reality, for the bright red rock is generally seen to pass down into the true shales. In some cases bands of flaggy limestone occurring in these shales are, when close to the trap, found to have the same pink color, and their surfaces weather into a soft velvety powder.

Section along the railway from Nalwar to Gulbarga.

An instructive section of the central part of the Bhima basin may be obtained by following the line of the Great Indian Peninsula Railway from Nalwar northward. For the first three miles it crosses dirty green and brown and thin red shales which extend as far as Halkatti (Halkatty) on the Allur nullah. From Halkatti northward to the edge of the Kogni valley is a spread of nearly horizontal beds of grey and light buff splintery limestones (Talikot limestones) largely quarried for railway building purposes. At the south edge of the Kogni valley the shale beds crop out, and in the valley the underlying gneissic rocks appear: the shales have thinned out till they are only from 30 to 40 feet thick. They re-appear north of the Kogni, though not close to the railway, but higher up the river valley and near Shahabad (Shawbad). The top beds of limestone exposed in the low hill south of the village are thinner than usual, rather silicious, and they contain also thin bands of chert. Four miles further north near Tegganur (Teggandoor) or Deyrun, the lie of the limestone and shale beds is not so

regular as usual, but they incline to the north-east at angles as high as 40°. A little further north they are covered up by the Deccan trap. The line of country is illustrated in Section I, Plate IX.

General characters of limestones east of the Bhima.

The limestones in the eastern part of the Bhima basin are the same as the usual grey, bluish, or fawn-colored hard splintery silicio-magnesian rocks met with in the central part of the basin, and they belong to the lower division of the great limestone band lying between the lower and upper shale series. In the Bennathora and Mulamari (Moolamurry) river valleys the limestones are more flaggy and earthy than elsewhere. The examination of the southern parts of the limestone area south of those rivers was incomplete.

Lie of strata generally undisturbed.

The position of the strata is generally horizontal, or they show a slight dip to the north or north-westward. There are occasional undulations of the strata, and in one case (which has already been described) between Parvatabad and Deyrun Tegganur, the strata dip at very high angles, or are vertical on either side of the axis of folding.

Brecciated limestone of Yeddihalli.

A very singular limestone breccia, the relation of which to the Bhima rocks now described is obscure and doubtful, occurs in the Agani valley and must here be noticed. This breccia forms a thin bed capping the gneiss to the west and north of the village of Yeddihalli, forming a rudely crescent-shaped patch with the horns of the crescent directed westward. It is very much obscured by the large spread of cotton soil which covers both the higher and lower ground of the Agani valley, but, as far as could be seen, it everywhere rests directly on the gneiss. From its external appearance it might at a passing glance be taken for a part of the Talikot limestone let down from the level of the plateau forming the south side of the valley, as in the two cases described at p. 152, where the soft shaley sandstones had been removed by denudation, probably sub-aërial, leaving the

hard limestone to sink gradually down to the level of the gneiss; but on closer examination the view will not be found tenable.

This brecciated limestone forms a homogeneous stratum, not a recent agglomeration of fallen fragments, and appears to have been deposited normally in its present position. The extremely sharp angles and delicate corresponding contours of the breccia fragments, which are cemented together by calcspar, preclude the idea of its having been formed by materials brought from even a small distance. It must have been fissured *in situ,* and then reconsolidated by pressure and chemical action into a tough and compact mass. In color this limestone is drab or cream-colored, weathering to a grey tint. Its position cannot be considered due to an overlap of the Talikot limestone beyond the shaley sandstone beds, for its southern boundary is so near to the plateau ridge that those shaley sandstone beds could not have thinned out in so short a distance.

The littoral character of the basement of the Bhima series renders it very unlikely that such a thoroughly pelagic formation as a pure limestone should have been deposited at the same period in such close proximity. The occurrence of many breccias of different characters in the Kaládgi rock series further to the west points to a period when similar comminuting forces were at work on a great scale, and there is no *primá facie* improbability against the supposition that this limestone breccia may be a remnant of former extensive deposits of that age, removed by denuding agencies prior to the commencement of the Bhima epoch.

Northern patch.

Another small limestone area which has been but slightly affected by the brecciating agency lies about three miles to the north of the Yeddihalli breccia bed, and, like it, rests directly on the gneiss. Like the Yeddihalli area, this is much obscured by the great spread of cotton soil, which renders it very difficult to trace the boundaries with any approximation to accuracy. At the southern end the limestone, which is here somewhat brecciated, appears faulted against the gneiss, the limestone itself being

tilted up for some distance along the line of fault to an angle of 30° to 35°. This inclination, however, rapidly decreases, and the beds become nearly horizontal before the east side of the area is attained. There can be no doubt these two outliers of limestone are of one and the same geological age. Not the faintest indication of any organism could be detected in them.

No organic remains or traces of such were obtained from any of the Bhima rocks, the one doubtful piece of fossil-wood or bone found at Kusukunuhal (see page 143) excepted. Mr. E. G. Balfour, Surgeon-General, Madras Medical Department, in writing to Mr. King and myself, claimed to have discovered some fossil at Gogi, which was lost subsequently. He did not describe its nature, and Mr. King, who made special search in consequence, was unable to find any organic traces.

Attention has already been drawn to the very strong general resemblance of the rocks composing the Bhima series to those of the Karnul series on the eastern side of the Peninsula—a resemblance due in great measure to the identity in lithological characters of the débris of the more ancient rocks of which both series have been formed, but also in all probability in large degree depending upon the similarity of circumstances under which the two series accumulated. Although in the absence of unquestionable organic remains and of stratigraphical evidence of synchronous deposition the exact correlation of the two series is not feasible, yet there is, from the very great petrological resemblance and from the geographical position of the two basins, a good deal to suggest the idea that they were once continuous and have been separated only by denudation.

There need be no hesitation in provisionally classing the Bhima rocks with the Lower Vindhyan series as Mr. King is inclined to regard the Pêm group of Mr. W. T. Blanford, an important group of sandstones and shales widely developed in the Godáveri basin, as the equivalents of the Karnul series, and this Pêm group is considered by Mr. Medlicott an undoubted representative of the Lower Vindhyans.

CHAPTER VI.

Infra-trappean Rock (Lameta Beds?).

Underlying the Great Deccan Trap series and resting sometimes on the gneissic and sometimes on the Kaládgi or Bhima series are certain deposits of sedimentary origin of small thickness and extent in which no organic remains have been found to show their age. Though of very small importance from their limited extent, they are yet interesting, as some of them may represent the pre-trappean deposits occurring in Central India, to which the name of Lameta beds has been given from their occurring typically at the Lameta ghát near Jabalpur. Some probably will be found to belong to the Deccan Trap period.

These deposits present a very different appearance from the hard rocks of the Kaládgi and Bhima series, though at times they occupy relatively similar stratigraphical positions, for, as a rule without any known exception, they are in a soft unconsolidated condition or at most only half consolidated. They are made up of the débris of the various older rocks occurring around, with a considerable admixture of red bole in nests or strings, or generally diffused through the mass.

The most common form these deposits present is that of soft marly or clayey grits, with or without included pebbles of the older rocks, especially of quartzite. Soft sandstones in thin beds and pure clays are much less frequently seen. In many places atmospheric agency has removed the matrix which enclosed the hard pebbles of quartzite, &c., and the latter remain as beds of loose shingle lying on the surface of the older rocks, but testifying by their presence to the former existence of the pre-trappean deposits.

At Nagurbetta.

The most easterly occurrence of these deposits was seen at the village of Nagurbetta* on the south side of the hill of the same name, which stands at the junction of the lowermost trap-flow with the gneissic beds, the inequalities of the surface of which latter are seen to be filled with red and white mottled grit in an unconsolidated condition. Higher up the sloping ground, south of the village where the Bhima beds appear forming an outlier, this mottled and sometimes clayey grit was not seen to occur. These Bhima beds have doubtless yielded the few quartzite and hard grit pebbles enclosed in the washed-up beds. The latter are rarely more than a couple of feet thick, and rest upon decomposing pink granitoid gneiss with many veins of coarse salmon-colored granite, the broken-up pink felspar crystals of which constitute the greater mass of the washed-up beds.

At Murálá.

Occupying the same position is the pebbly unconsolidated grit occurring below the trap on the north side of this Nagurbetta trap outlier and seen exposed in the rain-gully sections immediately south of the village of Murálá (Mooral Heereh), where it has a thickness of upwards of 7 feet. The grit here rolls about at low angles, as do the overlying trap-flows. No indication of organic remains were seen in these sub-trappean washed-up grit beds.

Near Muddebihal.

Drab-colored calcareous tufa, with one or two thin beds (2″ to 1′) of drab friable sandstone are seen exposed in a small network of rain gullies on the west side of the little outlier of trap lying two and a half miles south-east of Muddebihal. These beds are totally different in appearance from any of the formations which were noticed when describing the rocks of unequivocal Bhima age. They occupy only a few score square yards superficially, and apparently fill up a small depression in the gneiss.

* Near Nalutwar in the Muddebihal Taluq, Kaládgi district (N. W. quarter sheet 58).

In Dehwar Hulagbál nullah.

Occupying a similar position to the above-described rocks with reference to the trap-flows is a bed of gritty marly clay exposed to the depth of 5 to 6 feet in the banks of the nullah running eastward from Dehwar Hulagbál (Hoolugbal), a village lying about half-way between Muddebihal and Talikot. This gritty marly clay greatly resembles in its red and white mottled color the loose washed-up grit seen at Nagurbetta.

At Itgi.

To the west of Itgi (Eetgee), a village lying some five miles to the northward of Kalgi and nine miles west-north-west of Muddebihal at the junction of the trap-flows and gneissic rocks, the surface of the slope is largely covered with patches of massive kunkur-breccias of whitish color. The included fragments are small broken crystals of pink felspar in large numbers, lumps of gneiss, and a few quartzite and banded jasper pebbles. No trap was found among the included fragments, which could hardly be the case were the kunkur-breccia of younger age than the trap. This breccia seems to pass under the trap: owing to the excessively thick capping of regur no section could be found to prove this, but there is no reason to doubt it. The tufa is remarkably massive in character and very close-grained: its thickness may be estimated to be 4 or 5 feet as it now lies exposed on the slope of the rising ground. Not any trace of organic matter was observed in this remarkable deposit.

Other sections in which the gritty marly clays or clayey grits are to be seen were noted at Galgali (Gulgulleh) on the right bank of the Krishna to the north of Kaládgi; at Kulgur (Koolgoor), fifteen miles east-north-east of Gokák; and at Malanhatti (Mullunhuttee), three miles north-east of that town. At Guddgomanhal (Goodgomunhal), Rokatkatti, Rajunhal, and Jangwari villages lying on the long east and west spur of trap which stretched south of Kaládgi, and to the south-east of Aksurkop, the red mottled gritty or clayey beds occur, but are associated with much quartzite shingle which is generally coarse.

Similar coarse shingle is to be largely seen at Nagurhal, east of the Yellurgarh Trigonometrical Station hill near Belgaum, just at the boundary of the lowest trap-flow; but in this case it is mainly made up of gneiss and quartz pebbles, quartzite pebbles occurring, but rarely. The former existence of the infra-trappean beds is indicated by large deposits of quartzite shingle at Ghonchi and Narsapur, north of Torgal, and also at Kerur (Kehroor), and the adjacent villages of Malgi and Halkurki (Hulkoorkee). Along the boundary of the trap south-east of Aksurkop, a great deal of the infra-trappean shingle there exposed has been cemented into a sub-aërial conglomerate by a recent formation of hard calcareous tufa.

Old gravels supposed to be pre-trappean.

Far removed from the present boundaries of the Deccan trap area, but in all probability a relic of the pre-trappean beds, is a deposit of shingle lying on very high ground at Gundasagur (Goondasagur) and Kachapur, six miles north-north-west of Mudgal (Moodgul) in the Raichur Doab. Here the surface of the syenite-gneiss is strewn thinly over with quartzite shingle, with a few pebbles of gneissic rock. The quartzite shingle is well rounded and water-worn, but there is no existing stream which could have brought it there. The elevation of this patch of shingle is certainly not less than 300 or 400 feet above the cantonment of Ling Sugur, which itself is more than 1,500 feet above sea-level. The Krishna river also flows at a level lower by several hundred feet than the Kachapur plateau, which is the highest ground for many miles around, while the shingle lies but little below the apex of the plateau. There are now no quartzites whence such shingle could have been derived nearer than the Amingarh and Hanamságar hills, the nearest of them twenty-seven miles off, and separated by several wide and low-lying valleys; it is clear, therefore, that the shingle in question must be the remnant of an old conglomerate, formed at a period when the shape of the ground admitted of currents carrying quartzite pebbles to so elevated a point in the gneiss country. The shingle has

At Kachapur.

been but little weathered since its deposition on this spot, and was, therefore, probably only liberated from the matrix at a comparatively recent period, and from a matrix of much softer character than that of the enclosed pebbles.

At Idubhávi.

Of similar pre-trappean origin is perhaps another patch of quartzite and jasper gravel met with at Idubhávi (Idoobhawi), eleven miles north-north-east of Ling Sugur, at an elevation of about 200 feet above the present bed of the Krishna; an elevation the flood waters of the river cannot be supposed ever to have attained. The jasper pebbles are to all appearance of gneissic origin.

Some other cases of shingle deposits of doubtful age, but which may possibly have been of pre-trappean origin, will be mentioned in Chapter X.

Thin beds of sandy marl, semi-compact sandstone, and rather soft sandstones were found in many places along the boundary of the trap-flows; but nowhere exposed over more than a few dozen yards, and rarely so much, beyond the edge of the trap. In almost all cases they are much reddened near the point of contact with the trap, by the presence of quantities of bright-red bole.

Sigihalli section.

The most extensive exposure of these infra-trappean beds is near the village of Sigihalli (Seegeehullee), about ten miles east-south-east of Belgaum. The sandstones are here seen in very thin courses—in soft sandy marl resting on hornblendic schistose gneiss. The thickness of these infra-trappean beds may here amount to 8 or 10 feet at the utmost. No fossils were found in any case. The presence of bole in so many of the pre-trappean deposits appears to be due to the heating action of the trap-flows, poured on to beds of fine clay. The quantity of the bole is always largest close to the trap, where it occurs

Occurrence of bole in contact with the trap.

occasionally, being quite pure and much communited by minute cracks. The pure bole is rarely many inches thick. In some cases it is very markedly affected by a system of prismatic jointing on a small scale; but, unfortunately, the mass is so friable that it is impossible to collect any of the very pretty little prisms; they crumble under the most delicate handling.

From the circumstances under which they occur, from their limited extent, and from their strong lithological resemblance to the unquestionably fresh-water deposits among the lower flows of the Deccan trap, the infra-trappean beds may, in the absence of any more positive evidence, be fairly set down as of lacustrine origin.

CHAPTER VII.

THE DECCAN TRAP AND ASSOCIATED FORMATIONS.

Section I.—The Deccan Trap.

Character of scenery in the Deccan.

The general characteristics of the trap area in the south-western Deccan are low rolling downs with intervening shallow valleys, producing very monotonous and uninteresting scenery. This monotony of scenery is greatly enhanced by the large development of regur over the trap area, and the almost entire destruction of trees on the higher grounds. In many of the valleys there are numerous trees of fine growth, showing that the trap is not at all an unsuitable sub-soil for rich vegetation. Here and there, also, fine trees, protected by some superstitious association, remain on the highest grounds, showing that the present deplorable barrenness of the country is owing to the wanton improvidence of the people. The monotony of the scenery is in keeping with the great uniformity of the rocks, both in composition and stratigraphical arrangement.

As the trap area is traversed in a westerly direction, the scenery gradually changes in character with the rise of the ground and the appearance of younger and overlying trap-flows. The scenery is no longer so monotonous, for low flat-topped hills frequently crown the watersheds between larger streams, as to the north of Bijápur and to the north-west of Mudhól. Still further west the scenery becomes still better, as high and bold hills, the remains of yet later flows, are met with, such as the Bagedgúdda, north of Gokak, the hills around and west of Chikori, and the Kardigudi trigonometrical station hill, twelve miles east of Belgaum. These hills, especially the two groups first named, have been robbed of much of their beauty by human agency in utterly denuding them of all forest. Very nearly the same may be said of the Yellurgarh hill south of Belgaum, and of the fine group of hills

including the Sámángarh in the south-east corner of the Kolhapur territory. West of the Sámángarh hill, and of a line drawn thence southward to Belgaum, the hills become better clothed and *ipso facto* more and more picturesque as the edge of the ghâts is approached.

At the edge of the great scarp.

The scenery at the edge of the ghâts truly deserves to be described as generally very fine and often grand and really beautiful.

The scenery on the upper slopes and scarps is very similar to that seen on the Bor and Thall ghâts and familiar to very many, but it changes further down the sides of the hills, where the underlying older rocks are reached. Even in the ghâts the forests have been wofully thinned by the unhappy system of cultivation pursued by the hill people and known as the Kumari* system.

The annexed sketch, Plate VII, gives a correct idea of a very typical piece of scenery in the Kolhapur-Belgaum ghâts. It represents the view south-south-east from a high point south-east of Patgaon, towards the great spur rising south of the Amboli ghâts. The ghât is hidden behind the Mahadeogarh spur, along which runs the great scarp. The celebrated hill fort of Manohargarh and the east end of Mansantoshgarh show to the left of the picture.

Varieties of trap.

The principal varieties of trap met with in the southern part of the Deccan area are basalt, amygdaloid trap, vesicular trap, and clayey trap, which with some few intertrappean sedimentary beds and numerous highly ferruginous clayey beds (so-called laterite) make up the great mass of the trap-flows.

By far the commonest variety is the basalt with its compact and vesicular varieties. In it also must be included the extensive spreads

* In pursuing the Kumari system of cultivation, the natives clear a piece of forest land, cultivate it for two or three seasons, then abandon it and take up a fresh piece of forest land, to be used and abandoned again in its turn.

J. Schaumburg, Lith.

BASALTIC SCARP NORTH OF MAHADEOGARH SPUR-

MANOHARGARH AND MANSANTOSHGARH IN THE LEFTHAND CORNER.

of highly weathered earthy trap so commonly met with throughout the Deccan region, for they are the result of excessive weathering, and where the weathering has taken place concentrically, it is easy to find a nucleus of tolerably well-preserved rock in the centre of the spheroids. This variety answers to the nodular trap or wacke of older writers. The basalt occurs either massively amorphous, or rudely tabular, or rudely columnar, one or other of the two latter forms being most commonly met with.

The lower flows are mostly basaltic in character, the medium flows are alternately basaltic and amygdaloid, and the upper are chiefly basaltic, with clayey and lateritic beds capping them.

Infra-trappean land surface.

The lowest flows were poured out over an exceedingly rough surface, consisting of gneiss or the younger metamorphic rocks (Kalâdgi and Bhima series) and the thin local deposits described in the last chapter, which possibly represent the Lameta formation of Central India. Owing to this great inequality of the pre-trappean surface, it is impossible in many places to form a safe opinion as to the relative position of individual beds, for the basement bed in one place would correspond with a bed several hundred feet above the true base at another place. The upper flows frequently overlap the lower and rest upon the higher lying parts of the older rocks.

Position of the trap-flows.

In the ghât region the position of the flows is more distinct than further eastward, and they are seen, when carefully studied from some high and commanding point, to dip at a very low angle and generally to the north-east.* About twenty-five or thirty miles from the edge of the ghâts the dip becomes more easterly in direction, and so gradual as to be hardly recognisable by the unaided eye. The flows exposed in the Konkan show

* The dip is too slight to be measured with a clinometer, but a calculation of the difference in elevation of some of the principal trigonometrical stations which are capped by outliers of one and the same bed shows the north-easterly slope to range from 9 to 23 feet per mile, giving a mean of 16 feet per mile.

a very low westerly dip, as may be seen in Section No. 6, Plate VIII, in which Mr. Wilkinson has illustrated the structure of the country between the Phonda Ghât scarp and the sea at Malwan.

Course of rivers coincident with dip of flows above the ghâts.

The direction of the course of the upper waters of the various rivers rising in the ghât region and falling into the Krishna, coincides with the general dip of the trap-flows; it is probable, therefore, that the subaërial excavation of these valleys commenced immediately after the final outpouring of the last trap-flow, and has been progressing uninterruptedly ever since. Till the whole of the Deccan trap area shall have been geologically examined, it will not be possible to say which was the last flow, but if the youngest of those now remaining in the Kolhapur and Belgaum ghâts was really the last poured out, and thus represents the close of this epoch of tremendous volcanic activity, then the work done by atmospheric agencies since that period may be approximately estimated as a direct vertical erosion of from 1,000 to 1,500 feet in round numbers, the latter depth being that of the valley of the Yed Gunga in south Kolhapur opposite the great mass of Bhudhargarh (Buddurgurh), one of the eminences capped by the highest of the remaining trap-flows.

Extent of vertical erosion.

Present direction of monsoon does not quite coincide with the dip and direction of the valleys.

At present the most prevalent direction of the wind during the south-west monsoon, as indicated by the inclination of the trees on the highest and most exposed ridges, does not coincide exactly with the dip of the trap-flows and strike of the main valley, but is more westerly by one or two points of the compass.*

No traces of foci of eruption or of dykes.

No indications have as yet been discovered in the southern part of the trap area above the ghâts of the ancient centres of eruption, or craters, whence issued

* This applies more specially to the Kásarsadda, one of the highest ridges in the Belgaum ghâts lying south-west of Chandgurh.

the enormous trap-flows, nor were any true dykes of Deccan trap age met with, from which it may perhaps not be unsafe to infer that the volcanic foci whence the southernmost traps issued were situated at some distance north of such parts of the trap area as were visited in surveying the South Mahratta country and Southern Konkan. This view is supported by the great rarity of beds of volcanic ash in the south, though abundant and common in the northern parts. Two intrusions of basalt of doubtful age were noted by Mr. C. Wilkinson in the Konkan: one is a large dyke occurring at Sundur Wari; the other, apparently also a dyke, at Neoti on the coast north-west of Vingorla. He does not ascribe them to the Deccan trap series, but they differ from the ordinary dykes, mostly dioritic, traversing the metamorphic rocks in South India, by showing distinct columnar cleavage into pentagonal prisms. Of the second, he says in his notes, "The trap has broken the metamorphics and spread over them for a short distance. It can be traced northwards as far as Shepi (Shepee) in the ravine formed by the small stream which falls into the sea at Neoti." Though this looks very much like a small centre of outflow, the evidence given is insufficient to enable one to feel certain that the basalt in question really belongs to the Deccan trap series.

Thickness of the trap series.

The greatest thickness of the trap within the South Kolhapur area may be roughly estimated at from 2,000 to 2,500 feet, but increases northward. Further south the trap decreases in thickness, for the beds forming the southern boundary of the area near the crest of the ghâts are high up in the series and overlap by a wide space many of the underlying flows seen further north in the scarp overhanging the Konkan.

Subaërial origin of the Deccan trap.

The question of the circumstances under which the Deccan trap was poured out, whether subaërial, or subaqueous, does not need any further discussion, for it has been answered clearly and conclusively by Mr. W. T. Blanford, Deputy

Superintendent, Geological Survey of India, in his very interesting sketch of the traps and intertrappean beds of Western and Central India,* where he demonstrates the subaërial outpouring of the great lava streams.

Age of the trap series.

On the question of the age of the Deccan trap no fresh light has been obtained in working out its southern boundaries, for no fossiliferous rocks of determined age have been found either under- or over-lying the trap-flows.

It will be needful, ere the relative ages of the great trap-flows of the south can be compared with those of the north, that the ghâts and their great western scarp shall be examined from the Phondá Ghât to the Mahabaleshwar mountains.

Horizon of the intertrappean beds.

The position occupied by the intertrappean beds accompanying the traps is relatively the same as that of the corresponding beds occurring in Central India, for like them they occur low down in the series and near what will be shown further on to be (locally at least) its base.

Their position geographically.

The intertrappean beds are of small extent, and appear to have been formed in small lakes filling local depressions of the surface. They were observed only along, or near to, the south-eastern edge of the trap area.

Sections in the great western scarp.

The grandest sections of the trap series are to be seen in the great western scarp of the Sahyádri mountains; but these are often, from their vast size, difficult to study, as some of the great basaltic flows form long unbroken lines of cliff several hundred feet in height. They may, however, be advantageously examined along the two great military roads which have of late years

* Memoirs of the Geological Survey of India, Vol. VI, p. 145.

been carried up the face of the scarp,—one at Phondá Ghât connecting Ratnágiri and Kolhápur, the other known as the Amboli Ghât, and connecting Belgaum with Vingorla. The cuttings along these two noble roads give almost perfectly continuous sections of the whole thickness of trap-flows they cross, and it would be easy for any one having the necessary time to make a close measurement of the different flows there exposed.

In the Phonda and Amboli Ghât road.

To the east of the mountains the best sections are afforded by the bare hills around Chikóri (Cheekoree) in the Baged Gudda north of Gokák and the Yellurgarh hill south of Belgaum. The more easterly extension of the area is well illustrated by the sections to be seen in the Horti hills north of Bijápur, the Nagurbetta (hill) west of Ling Sugur, and still further east by those in the various plateaux between Gulbarga and Bidar (Beeder). These will be referred to separately further on.

Other sections further east.

The amount of denudation which the Deccan trap has undergone on the western side of the Sahyádri range is abundantly manifest in the tremendous scarp which remains. The extent to which the trap has been denuded can be measured by thousands of feet. In the Sáwantwári country nearly the whole of the vast mass of hard lava flows has been removed, and many hundred feet of the underlying gneissic rocks as well, while further north, nothing but the very lowest of the trap beds remain. The great terrace of the Konkan may be regarded as a vast shelf-like plane formed by marine denudation, the comparative level of which has been destroyed since its elevation above the sea by the tremendous atmospheric energy of the south-west monsoon.

Denudation of the western scarp and Konkan.

The trap beds which run under the sea northward of Vingorla are probably the lowest members of the Deccan trap series anywhere exposed, but unfortunately no

Lowest flows.

fossiliferous rocks underlie them to show when they were poured out. They are most probably of much greater age than the basement flows seen above the ghâts, and in the Deccan they may also be much older than the basement flows in Central India.

Mural scarps.

The great mural precipices in the western scarp are all in basaltic beds; many, if not all, of which show rudely prismatic cleavage, a feature to which in all probability they owe the comparatively very small amount of change they have undergone. In this they differ widely from the horizontally-jointed flows in which very extensive decomposition into a ferruginous vesicular quasi-lateritic iron-clay has taken and is now taking place.

Chikóri section.

The series of flows seen in the bare hills surrounding the taluq town of Chikóri, in the northern part of Belgaum district, consists of six basaltic flows, the three lowest of which are separated from each other by thin beds of amygdaloid trap and red bole, the latter lying irregularly on the rough surface of the amygdaloid. The upper flows are themselves separated by thin boliferous beds, part of which may be volcanic ashes. The two middle flows, though quite distinct, show no intercalated matter. The whole makes up a thickness of 600 to 700 feet, of which the three lower basaltic flows occupy fully two-thirds.

Section on Baged Gudda.

A very good section is also afforded by the bare flanks of the Baged Gudda, which is a bold table-topped mass attaining an elevation of 2,667 feet according to the Great Trigonometrical Surveyors, and standing 700 to 800 feet or more above the general level of the country. The flows here as seen from the south are eight in number, over the watershed ridge dividing the valleys of the Ghatprabha and Krishna. They are much more easy to distinguish from a distance, as the ruggedness of the slopes often

masks the terrace structure when an observer is on their flanks. The succession is as follows* :—

1. Iron-clay (laterite).
2. Amygdaloid.
3. Basalt.
4. „
5. Amygdaloid, red and brown.
6. Basalt.
7. Amygdaloid, purplish, soft.
8. Basalt.

Illustrative of surrounding country.

The lower beds here exposed extend far around on all sides, and may be traced by the eye for many miles in the various spurs branching away from this great mass, which is the most easterly in which the uppermost flows are met with in this region. The lower flows connect the Baged Gudda spur with the group of high trap hills east and north-east of Manoli, and with those forming the Chikóri hills, as well as with the lower basaltic plateau ridge (underlaid by amygdaloid) extending eastward along the northern frontier of the Mudhól State till they meet the two ridges of quartzites forming the Jamkhandi hills. To the north the lower flows form several rocky ridges, stretching away into the Krishna valley. The hills north of the Krishna near Athni (Hutnee) and Goteh may safely be said to be made up of extensions of the Baged Gudda series. Further east and south-east, as the ground sinks, it is difficult to trace the extensions of the flows with certainty, as great surfaces are covered up with thick spreads of cotton soil and other superficial deposits; this is the case with a flow of doleritic trap occurring at and around Mudhol, where it is doubtful whether it underlies or overlies a flow of amygdaloid which occurs to the north of Mudhol near Sirul (Serool). The doleritic and basaltic flows forming the group of hills at Gosbal and Kaujalgi (Kowjulgee), east of Gokák, judged by the level they occupy, represent the three lower members of the Baged Gudda sections.

* The flows given are only the important ones which form distinct features; smaller flows and partings were not reckoned.

Iron-clay or lateritic bed.

The iron-clay bed which caps the Baged Gudda is an outlier of a very important bed of that remarkable rock so often called laterite. This bed is important, as being the youngest known, the most constant, and most safely determinable member of the Deccan trap series in this quarter.

The "summit bed."

This particular iron-clay bed caps all the highest ridges and peaks in the Kolhápur and Belgaum mountains, and may therefore be called not inaptly the "summit bed." Of all the mountains, those which it caps are the most perfectly table-topped, and in most cases the capping is sharply scarped all round the edge. As these scarped plateaux crown all the highest hills, and were easily rendered very strong, many of them were chosen by native chiefs as sites for their strongholds, such as the Yellurgarh, Máhipálgarh, Kálánandigarh* (Kalanuddeegarh), and Gandharvagarh (Gundhurvugurh) in the Belgaum ghâts, and Bhudhargarh and Sámángarh in South Kolhápur. Wallabgarh and Paizárgarh in the Chikóri taluq are also both of them built on small outliers of this iron-clay bed. The flows underlying this iron-clay bed show great similarity throughout the extensive area they cover.

Fortified outliers.

Correspondence of terraces.

The correspondence of flows in different great spurs is especially clear in the three ridges into which the Bhudhargarh spur divides; it is admirably seen when looking westward from the high bluff on the eastern ridge which towers over Belwarree. The view northward from Bolaee at the northern end of the lofty part of the western ridge on which the Bhudhargarh itself stands, shows this correspondence and extension of the flow-terraces most distinctly in all the ridges on either side of the Yed Ganga valley, and

* This fort is called "Kalanidhigad" in the official list fixing the spelling of names, but it is generally and locally known by the name given above and not by the other. I was corrected by the people when I used the official name.

in others beyond as far north as the Panhála mountain, north of Kolhápur. The continuity of the flow terraces between the Bhudhargarh mass and the Chikóri and Baged Gudda sections is obvious on the most cursory inspection of the north side of the very bare ridge south of Nipani (Neepanee). The geological structure of this great spur of the mountains is generally more distinct and clear than that of the less extended spurs further south.

Continuity of flows.

Underlying the great iron-clay bed, which will be again referred to in some detail further on, is very commonly a bed of clayey trap, often purple in color, and much softer than the overlying ferruginous bed. The more rapid weathering of this clayey trap bed is the cause of the scarp constantly and sharply defining the ferruginous summit bed. This clayey trap generally passes down into ordinary purple or reddish brown amygdaloid, below which are basaltic and other amygdaloid flows. The clayey trap is largely developed on Kálánandigarh and Sámángarh, also on Bailur (Byloor) trigonometrical station hill,* where it is well seen to pass into a fine amygdaloid. It is also well seen on Wallabgarh and Paizargarh in Chikóri taluq.

Clayey trap.

Sections where seen.

A somewhat striking feature of one of the basaltic flows, which, at many parts of the southern boundary, forms the basement bed, is the weathering into great rude blocks, some of which might almost be reckoned small tors. These frequently rest directly on the underlying gneiss and form a very conspicuous boundary. Very often a few big blocks remain isolated on the gneiss surface at small distances from the boundary of the flow itself, *e. g.*, at Bastwar, south-west of Belgaum, also near Nagurhal, east of the

"Blocky" weathering of basement beds.

* 14 miles S. W. of Belgaum, and the highest point of the Great Trigonometrical series in this part; its elevation is 3,491 feet.

Yellurgarh, and to the north-west of Murgód. At Bavihal, two miles north of Sampgaon,* an unusual variety of trap occurs below the blocky basaltic flow which forms the base generally in that quarter. This exceptional variety differs from any other flow belonging to the Deccan trap series in being much more crystalline in texture, and resembling far more a highly hornblendic diorite of gneissic age. In color it is intensely black or greenish black. It is certainly unconformable to the gneissic rocks exposed a little distance to the south, and as far as can be seen, for the great spread of cotton soil is conformable to the overlying basaltic flow, from which it is separated by a thin bed of boliferous clay. The upper part of the intermediate bed consists of pure bright-red bole, 2 to 3 inches thick, which shows very distinct prismatic columnar cleavage.

Aberrant variety of trap.

Typical basalt occurs in innumerable places, of which it will suffice to name one, where it is largely quarried, namely, on the slopes of "One Tree Hill" north of Belgaum. It is a fine close-grained brownish black stone, with a few small vesicular cavities.

Basalt, typical.

A variety, which is porphyritic, from enclosing rather large crystals of green glassy-looking olivine, was observed on the high hill forming the north-eastern extremity of the Yellurgarh ridge, and also further east in the basaltic plateau lying south of Batkurki (S. W. of Kaládgi). A similar rock, but containing glassy felspar, instead of olivine crystals, is mentioned by Mr. Blanford as occurring in the northern and north-eastern parts of the great trap area. The main part of the great spur of trap running into the centre of the Kaládgi basin is basaltic. A few unimportant amygdaloid beds occur here and there, one of which, between Batkurki and Dadiberi (Dadeeberree), may be mentioned because of the exceeding minuteness of the

Porphyritic variety.

* Sampgaon is the chief place of the taluq of that name, and lies 5 miles N. of the Malprabha and 16 miles E. S. E. of Belgaum.

vesicles, which gives the rock somewhat the appearance of a speckled grit.

Basalt and amygdaline south of Bijápur.

North of the Krishna, towards Bijápur, the undulating ground shows much amygdaloid in the valleys and low grounds, while the intermediate ridges are capped by a thin basaltic flow. The lowest flows seen near the Krishna are all basaltic. Further east still, near Muddebihal and Talikote, the general character of the trap is basaltic.

Volcanic ash-beds.

Volcanic ash-beds were not met with numerously within the southern parts of the Deccan trap area, though doubtless more would have been made out had not the exigencies of work rendered it necessary for the survey of much of the trap country to be very cursory. Those noted were in the flanks of Wallabgarh, and of that portion of the north Ghatprabha range between Chikori and Wultur in south Kolhápur. Other beds were also observed in the amygdaloid trap region at and south of Bijápur. At first sight, the beds may easily be taken for amygdaloid flows, but a closer inspection shows them to be made up chiefly of fragments, "lapilli," and dusty particles of vesicular trap, which are cemented together by the deposition of calcite and zeolitic matter in strings and films between the fragments, as well as in the vesicular cavities. The lapilli are mostly of reddish or purplish color, and much red bole is diffused through the mass, which, by contrast with the whitish calcite and zeolite, gives the whole a reddish or pinkish-grey color.

Some of the argillaceous traps suggest the idea that they were formed of exceedingly fine dust, subsequently semi-consolidated by infiltration of clayey matter.

Enclosed fragments of older rocks.

At the base of a much-weathered earthy-looking mass of trap almost in contact with underlying quartzite, a few hundred yards west of Shengaon, in the valley of the Ved Ganga in Kolhápur State, numerous fragments, small and large

(8″ to 10″ in diameter), of gritty quartzite, occur enclosed in the trap. The enclosed fragments show no trace of change on their surfaces; but the section is not a satisfactory one, both rocks being much weathered and a good deal obscured by mud, brought over the surface by a small stream. This was the only case observed of fragments of older rock enclosed in one of the Deccan trap-flows.

Decomposition of trap rocks.

The decomposition of the trap rocks under certain circumstances gives rise to eminently clayey products containing a very variable, but often very large, percentage of iron; under other circumstances the rock simply breaks up into soil varying in character according to the nature of the parent rock. The former kind of decomposition will be separately considered in a special chapter further on, the results being features of striking import in the geology of these rocks. The soils formed by the second kind of decomposition will be described in Chapter X, which deals with superficial deposits.

The decomposition of many varieties of trap into ferrugino-argillaceous materials may be seen taking place in endless sections, more especially in the case of basaltic flows, in which the rock cleaves horizontally into a quasi-bedding. Some very good instances of this are to be seen near the top of the Amboli Ghât road. In columnar trap, however, this degradation into a yellow crust, first of ochrey and then of lateritoid character, is not at all or only very rarely seen; this is most likely due to the much greater rapidity with which percolating waters flow off because of the numerous vertical joints, while they often lodge in the horizontally-bedded traps for much longer periods.

Nágurbetta section.

A very good section is to be seen on the flanks of the Nágurbetta,* about four miles north-north-west of Nálutwar, and there the trap formation seems to be made

* The Canarese word "betta," forming the termination of the name Nágurbetta, signifies a hill or mountain.

up of these flows, the two uppermost of which form distinct bands or narrow terraces round the hill, which is capped with a porcelanoid iron-clay bed, to be described further on. The aggregate vertical thickness of these several flows is probably between 300 and 400 feet. The basement bed here consists of an earthy dirty pale-green colored mass of nodular trap, wonderfully broken up by the spherical weathering. The concentric laminæ are very friable, but the nuclei, which are generally small (rarely larger than an orange), consist of hard and tough bluish or greenish basalt, enclosing a few grains of a bluish-white quartz-like mineral. This flow forms a plateau (resting partly on the gneiss, partly on the basement beds of the Bhima series, here consisting of grits and conglomeratic sandstones), from which rises the conical hill. The two upper flows consist of hard basaltic trap, the division between them being formed by a band of extra hard and compact basalt, the horizontality of which is fairly seen from a distance. Amygdaloids of chalcedony or quartz of small size are rather numerous in these hard beds, and leave many small pittings on the surfaces of the weathered blocks. This Nágurbetta forms the culminating point of a large outlier of trap.

Thickness of flows.

Another interesting section occurs on the north side of this outlier, immediately south of the village of Hire Murala (Mooral Heereh), about three miles west-by-north of the Nágurbetta. The following succession of beds is here seen in the sides of a deep rain gully :—

Murála section.

1. Earthy trap (nodular trap), much weathered into spheroids, green-grey to yellow brown in color (basement bed at Nágurbetta).
2. Bluish-grey clayey trap, 10 inches to a foot thick.
3. Clayey trap with waxy lustre, apple-green and brown mottled 1′-4″ thick.

The last bed rests on an unconsolidated pebbly grit, which is in parts marly. A thickness of 7 feet of this pebbly grit is here seen exposed;

its surface had been very irregularly eroded before the deposition of the trap-flows, which have filled up the irregularities of the surface. All the beds exposed in this section roll about at low angles.

The general surface over which the trap was poured out was a highly irregular one, the Bhima rocks having been greatly eroded at some earlier period and having themselves been deposited over a very rugged sea bottom of the gneissic rocks.

Bairapur hill outlier.

The two basaltic flows which remain as a capping outlier on the summit of the Bairapur (Byrapoor) trigonometrical station hill, nineteen miles north of Ling Sugur (Sheet 58, N. W. quarter), are very unusually vesicular for a rock otherwise so hard and close-grained.

Columnar cleavage.

A tendency to prismatic cleavage in the basalt was noticed in several places, but it is but a rough approximation even where most marked.

In the eastern part of the trap area in the Deccan plains, the prismatic tendency is only seen where the trap has been denuded to an approximately flat surface, when it resembles an extremely rude tesselated pavement, the tesseræ forming rather irregular polygonal figures. When broken out from the mass, the prisms are found not to be longer than their average diameter, or very little so, and in no case did they merit the appellation of columns. Examples of this may be seen in many places, as Lukoondi, Shellugi, Pirapur (Peerapoor) and, Tallihally to the north-east of Talikot, just on the boundary between the Kaládgi district and the Sorapur taluq of the Nizam's dominions.

The trap here is black, with many rusty spots, and of gritty texture, but has a fairly metallic ring when struck. To the east of Pirapur there seem to be two flows of hard black basalt recognizable on the sides of the scarp in which the trap plateau terminates. One

of these forms the basement bed here, and none of the earthy pale-green weathered trap is seen along the scarp.

In the more western parts of our area columnar cleavage is occasionally seen, but is generally very rude in kind and deserving no note. It is most frequently seen in the basaltic scarps on the western slopes of the Sahyádri range, but is nearly everywhere extremely rude, and in no way to be compared with the columnar cleavage seen at Staffa, the Giant's Causeway, and numerous other places well known to all students of Geology. The best case that came under my notice is probably that in the cutting at the very top of the Phondá Ghât, and even there the columns are very rude, but Mr. Wilkinson noted fallen masses of trap with perfect columnar structure in the valleys below the Bhekurli spur west of Rám Ghát.

The extreme eastern part of the trap area coming within the scope of this report is thus described by Mr. King, who surveyed it:—

Sections at and near Gulbarga.

"The most prevalent and conspicuous rock is still a dark-green or somewhat brownish massive dolerite, at times very compact and splintery, when it is often of a somewhat greyer color and then more easily weathered and decomposed than the usually coarse-grained variety. Minute particles of olivine are frequently interspersed through the rock. Neither of these varieties are often vesicular, though very often minutely so, while they contain at rarer intervals small amygdala, geodes, and masses of semi-translucent chalcedony.

"Gulbarga is situated on nearly the lowest flows of a series which forms the major part of the low flat-topped hills around, as well as the high ground to the north-east, on which stands the great 'Gumbaz,' the tomb and shrine of Sháh Náwaz Khan, the greatest saint of the Deccan.

"The lower part of the town to the south and eastward stands on a not very compact and easily weathering variety, with thin bands of

highly vesicular and amygdaloid trap full of kernels of scolecite (often coated with green-earth), minute particles of which glisten all over the surface in this part of the town. These flows of vesicular trap, weathering into a clayey substance, show strongly in the wider valleys north-east and east-north-east of Gulbarga; while the higher plateau in this direction are of massive dolerites which often exhibit rudely spheroidal weathering.

"The following section was observed on the Durga hill, north-east of Kaulagi, and some twenty miles east of Gulbarga. It includes about 150 feet of the lower trap-flows. The bottom beds are dark, greenish-brown, nearly black, compact trap, showing in the low ground up to the base of the hill about 30 or 40 feet. Then a greyer colored and much weathered variety seamed with laminar and nodular masses of brown and yellow common opal (? chert) and white and semi-translucent chalcedony in various forms. The rest of the hill upwards is coarse, massive dolerite, weathering into a coarse greyish-green somewhat clayey rock with very little chalcedony.

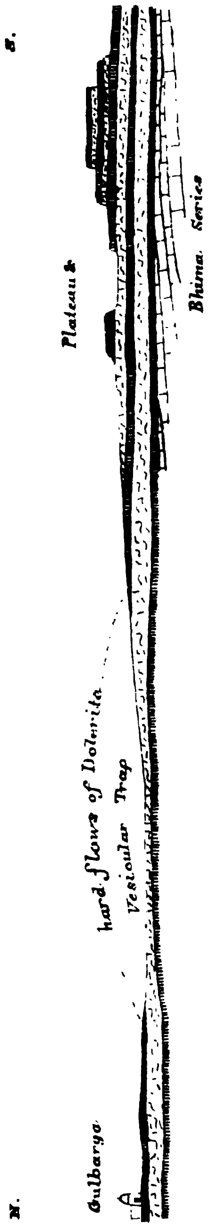
"Further north-east, yet more elevated plateau show the summit of the Durga hill to be continuous with them, and to be overlaid with other amygdaloid flows and still higher-lying flows of massive trap.

Scarps and terraces.

"The scarped and terraced character of the country so conspicuous in parts of the Deccan is very well displayed, though on a small scale, all over this part of the country; the thickness of the trap formation being from 100 to 300 feet between Kaulagi and Bidar. There was not sufficient opportunity for observing whether the harder flows of trap forming the terraces of the different plateau-like hills are constant over any great distance.

"In the neighbourhood of Gulbarga there are five hard flows, the higher parts of the town being situated on the second of these,

while the fourth constitutes the hard capping of the cotton-soil covered plateau to the south-east, as in the accompanying diagrammatic section.



Alternation of trap-flows south-east of Gulbarga.

"In the higher plateau to the north-east of Hoomnabad, Yekali, &c., there are possibly four more flows than those given above, where the highest, on which Bidar stands, is reached. The flows thus indicated are only the harder and most distinct; there are doubtless still many intermediate ones of dolerite which are not so evident on the steep slopes of the hills, owing to the softer and more amygdaloidal flows between being often of no great thickness."

Bidar stands upon the highest flows.

The mineral substances enclosed in the trap-flows are not very numerous, less so indeed than might be reasonably expected over so vast and varied a tract. Zeolites are very abundant in small or large vesicular cavities in many trap-flows. They very rarely indeed occur in drusy cavities of sufficient size for the crystals to be made out by simple inspection. The most common zeolites are scolecite and stil-bite. In one instance an uncommon crystalline form of heulantide was obtained in a purple amygdaloid occurring at Dandapur, 9½ miles north of Gokák. The

Included minerals.

Zeolites.

crystals occurred as lining to irregular clefts in the rocks, not in regular drusy cavities.

Agates.

Agates are not commonly met with of large size. They are most frequently found in the highly decomposed basaltic beds which are so often to be seen throughout the trap area. As a rule, with but very rare exception, the agates are made up of white or bluish-white chalcedony in concentric bands with generally a central cavity lined with quartz crystals of different sizes. Not a single agate showing bright colors of any kind was seen, and only three geodes were found in which the central cavity was lined with amethystine quartz of pale color. These were met with in one of the very lowest flows close to the bottom of the old ghát road at Phondá Ghát. Numerous geodes full of very compressed crystals of limpid quartz accompanied the amethystine geodes. The geodes here found were much larger than any seen elsewhere; specimens ranging up to a child's head in size, but generally much smaller, were here met with, all imbedded in an earthy brownish basalt flow.

Smaller agates are found in large numbers on the weathered surfaces at the following places: On the ridge north of Chinchni, three miles west of Chikóri; at Kurgaon, eight miles south-east-by-south of Chikóri; at Koluti (Kolootie) on the banks of the Krishna, eight miles west of Jamkhandi; near the ruined village of Hamamsagur, twenty miles east-south-east of Gokák; north of Karikol (Kareekol), a village till lately belonging to the Kolhapur Jaghir of Torgal; and lastly, at Hanamapur, five miles south-east of Batkurki in Badami Taluq.

Fungoid concretions.

Some very curious fungoid concretions of chalcedony and rock crystal combined are found in a soft clayey (weathered?) amygdaloid flow south-east of Deh-mangi, four miles south-south-east of the fort at Belgaum. This and the

Near Belgaum.

Kálánandigarh were the only localities at which they were met with in the Deccan, but some concre-

tions of identical character were found by me in a bed of trachytic agglomerate, crossed by the lower zigzags of the path leading from the cantonment at Aden up to the signal station on Jebel Shem Shem. These Aden specimens were smaller and less beautiful than the Indian ones.

In Aden.

Calcspar occurs very frequently with both basaltic and amygdaloid trap. Traces of crystals of calcite often show on or inside geodes of agate; in most cases the crystals are six-sided pyramids or "dog's-tooth" crystals.

Calcite.

Magnetic iron occurs commonly diffused through the mass of the basaltic and doleritic traps and in considerable quantity, as may be seen by the large quantity of magnetic iron-sand carried down by almost every stream flowing across the trap rocks.

Magnetite.

Arragonite was found in occasional radiated amygdala in the doleritic trapflows, *e. g.*, near Múdhol.

Arragonite.

Red bole occurs frequently in amygdaloid beds and in some volcanic ash beds, *e. g.*, in the flanks of Wullubgarh and at Turweh (Toorweh) near Bijápur.

Bole.

Green earth is not very often seen even in amygdaloids, but occasionally it occurs in films coating the individual amygdala included in the mass.

Green earth.

Olivine, usually so common in basaltic rocks, is not very often seen owing to the greatly weathered condition of the basaltic flows and to the great rarity of quarries in which freshly exposed surfaces may be examined. The best specimens met with were found in the flow forming the watershed plateau south-east of Batkurki (12 miles south-west-by-south of Kaládgi), in the first high basaltic hill south-west of Nelserri Travellers' Bungalow on the Belgaum-Kaládgi road, and in Maswa hill north of Shengaon in the Ved Ganga valley.

Olivine.

Section II.—Intertrappean Beds.

Between some of the different flows of lava making up the Deccan trap series, occur sedimentary formations, which, where they have been found fossiliferous, prove, from the nature of their organic contents, to be of fresh-water origin. From the similarity of mineral character, there can be very little doubt but that all these formations, at least in this part of the world, were formed in fresh-water lakes or jhils.

Fossils.

The fossils found were *Physa Prinsepii*, a small delicate species of *Lymnæa* and *Unio Deccanensis*, all species typical of the intertrappean deposits in Central India near Nágpur and elsewhere, thus proving that the traps of both regions belong to one and the same period.

Mode of occurrence and mineral character.

The number of intertrappean beds found in the South Mahratta region is small, and they are of small extent laterally and vertically; being apparently mere local deposits. In mineral character they differ much from the majority of the Central Indian intertrappeans which are calcareous (limestones or calcareous grits) or cherty, while those in the south are chiefly arenaceous deposits, sandstones, conglomerates, grits and clay beds.

Of the southern intertrappean beds only one was found to be calcareous and one cherty, and unfortunately neither proved fossiliferous.

The intertrappean beds found in the South Mahratta Country all lie low down near the base of the trap series. In one important case a fresh-water marl was found to be resting directly on the gneiss rocks and underlying, therefore, what locally appears to be the lowest trap-flow. Whether this flow really represents the lowest of the series, or has merely overlapped some yet older flow, could not be determined, but from the shape of the ground, it appeared quite probable that it might be a case of simple overlap against an old rising ground of the original gneiss surface.

But this does not seem of very great importance, for there is no reason why one of the fresh-water lakes above spoken of may not have existed prior to the first pouring out of the Deccan trap, and have been filled up; its deposits being thereby preserved from denuding action to the present time.

Although very many sections of these marls, clays, and sandstones were examined carefully, it was only in three that any organic remains were found; the one just referred to occurs at the village of Todihal on the south bank of the Krishna (four miles north-west-by-north of Bilgi, and fifteen miles north-north-east of Kaládgi); the second a mile west-north-west of Mamdapur, and six and a half miles south-east-by-east of Gokák; the third at Uparhatti, a mile north of the second locality.

Physa bed at Todihal.

The Todihal section is about two-thirds of a mile south-east-by-east of the village. The section is not very distinct owing to the quantity of soil (a mixture of decomposed trap and regur) covering the edges of the several formations, but by making some excavations, the lie of the beds was ascertained sufficiently to understand their real relations.

The outcrop of the marl is so much masked that attention would not have been attracted to it, but that a specimen of *Physa Prinsepii* was seen lying loose on the surface. Even then it was not till after I re-visited the section and made several excavations that the source whence the *Physa* came was ascertained with perfect certainty.

The thickness of the marl bed is from 6 to 8 feet at the spot where I made the excavations. The fossils contained in the freshly-exposed marl were extremely brittle and difficult to extract entire, but those which had been weathered out were in very good condition. Only one or two showed any trace of silicification, the test being unaltered except in color in most cases. A large percentage of the shells were found to be

much distorted and crushed out of shape, the effect, doubtless, of heavy pressure from the mass of rocks which had been piled over the original shell marl.

The shells found belong to three, or possibly four, genera, namely—

Physa Prinsepii, and perhaps another species.

Lymnea.

Unio Deccanensis, or a very closely allied species; fragments only found.

The other form of *Physa* is a shell equally sinistral in whorl with *Ph. Prinsepii*, but much like an *Achatina* in shape.

The *Lymneæ* strongly resemble a long elegant form figured by Hislop in his very able paper on the geology of the Nágpur country.*

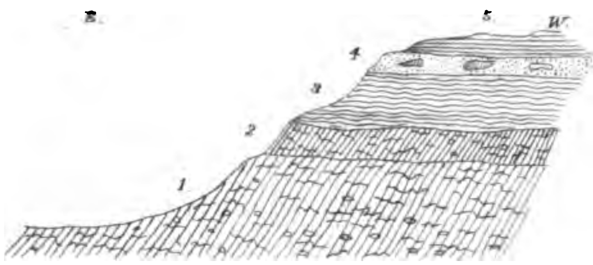
A broken specimen of *Unio Deccanensis* was found by a horse-keeper in the bed of a nullah ten and a half miles east of Mamdápur near Melikeri (Mehlee Kehree), a place which there was no opportunity of re-visiting to trace the source whence the fossil was derived.

Mamdapur section.

The intertrappean beds near Mamdapur in Gokák taluq present the appearance of having been formed on the margin of a lake. There is a considerable show of bright-red sandy marl, the red color being due to the presence of bole in some quantity. Under the marl is a thin bed of sandstone resting upon other red sandy marl which overlaps on to the gneissic rocks to the east. The whole surface is greatly cut up by atmospheric action, but near the centre a solitary small outlier of spherically weathered basaltic trap caps the upper marl beds. The underlying trap is exposed in sundry small gullies, and is seen to fill a depression in the gneiss surface. The

* Quarterly Journal of the Geological Society, Vol. X, p. 470.

annexed diagrammatic sketch represents the section seen in one of the rain gullies near the northern part of the intertrappean area.



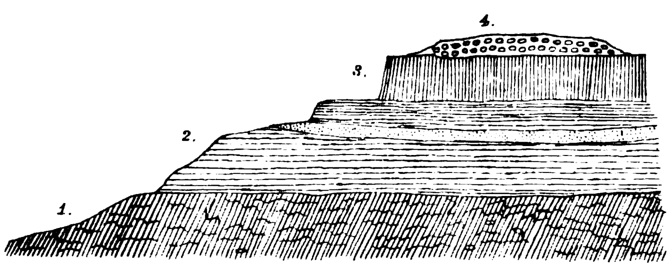
Section of intertrappean beds near Mamdapur.

5. Red sandy marl with kunkur and many pebbles of gneiss and quartzite.
4. Sandstone with lumps of quartzite and shells of *Unio* (*Deccanensis?*)—matrix of pale drab color.
3. Red marl like No. 1.
2. Greenish-yellow marly-looking bed of decomposed vesicular trap passing down into
1. Dark greenish-black vesicular trap with many small and a few large amygdaloids of agate.

The total thickness of the marls and sandstone ranges from 15 to about 20 feet.

Uparhatti section.

A little more than a mile from the Mamdapur section, but separated from it by an exposure of the gneissic rocks in the bed of the great Mamdapur nullah, rises a low, flat-topped ridge, on the west side of which, close to the village of Uparhatti (Ooparhuttee), the intertrappean rocks are again well exposed as shown in the accompanying sketch diagram..



Section of intertrappean beds at Uparhatti.

The beds exposed in the section are—

4. Quartzite and gneiss shingle of uncertain age.
3. Weathered basaltic trap.
2. Red sandy marl with three or four sandstone partings containing *Unio* (*Deccanensis ?*).
1. Decomposing whitish amygdaloid trap.*

The *Unio* beds are about 20 feet thick, and there can be little doubt that they were formerly continuous with those of the Mamdapur section. The fossil *Unios* in both sections are very well preserved, the interior nacre even being preserved in some instances. They do not seem to have been exposed to so severe a pressure as the Todihal *Physas*, or else the matrix they were enclosed in had acquired more power of resistance ere the pressure supervened.

Supudla sections.

The most important example of intertrappean beds in which no fossil remains have been found is to be seen at Supudla (Soopudla), six and a half miles north of Ramdurg, where the following set of beds rests upon the basement trap-flow, and is well exposed in the slope east of the village:—

6. Trap.
5. Red bole, a thin band.
4. Red and white mottled sandy marl.
3. Friable sandstone.
2. Conglomerate sandstone with quartzite pebbles.
1. Trap.

The beds lie horizontally, and may safely be estimated to be 20 feet thick and may possibly be more.

About two miles to the south-east in the left bank of a nullah running south into the Malprabha is a small section exposing a bed of sandy red marl resting on a coarse conglomerate of quartzite shingle, at the base of which are large angular and sub-angular masses of quartzite

* The section represents the beds north of the village in order to introduce the curious shingle bed No. 4. The *Unios* were found a few dozen yards south of the village.

which rest on a clayey vesicular trap itself in contact with the Lower Kaládgi quartzites.

"Relic" Patches of shingle.

Patches of shingle, consisting of quartzite or quartz, but chiefly the former, were met with at several points in the trap country in such positions that it was evident they were relics of some intertrappean formation which had been removed by denudation, or which was masked from observation by superficial detritus. To the latter class apparently belong the patches of such gravel met with at Kolik and Chiguli (Cheegooleh) on the south side of the great Tillar ravine west-south-west of Belgaum. This shingle was traced up to the base of the high trap ridge south-east of the former village, on the south side of which ridge is the source of the Malprabha river, but no section could be found showing the shingle and trap *in situ*.

A similar gravel patch occurs at Walmanni, a mile east of Jamboti, and at much the same level relative to the trap-flows. Another in which quartz pebbles predominated, was seen near the western extremity of the great trap spur north-west of Párgarh, some four miles west of Rám Ghát.

To the first class of such gravels, probably the relics of former inter-trappean beds, belongs, most likely, a large spread of quartzite shingle lying on the surface of the trap on rather high ground, 3 or 4 miles north of Yádwád, at a level to which the waters of the Ghatprabha are not likely ever to have risen.

The curious bed of quartzite shingle capping the Uparhatti hill and mentioned in the note on the opposite page, may also not unreasonably be held to belong to the class of relics.

Whether any of the numerous lateritoid rocks that so frequently appear to be intercalated between trap-flows in the high ridges of the ghát region be not of intertrappean sedimentary origin is a problem

which remains to be solved by future observers. Their position frequently suggested such an origin for them, but sections showing their relation and real nature are so rare that no satisfactory conclusions were arrived at. Some of these were the iron-clay beds, alternating with trap-flows, on the south side of the great Jamboti ridge seen on the path leading from Chikli (Cheekhleh) to Amoteh.*

Oolitic calcareous beds near Nelserri bungalow.

The only instances of intertrappean limestone met with were two small exposures of flaggy limestones, oolitic in structure, light brown or whitish in color, occupying depressions in the surface of the trap,—one in the hollow at the foot of a hill a little off the high-road south-west of Nelserri Travellers' Bungalow, the first stage between Belgaum and Kaládgi; the second exposure occurs at Ghone, a village six miles east of Nelserri. No signs of organic remains were seen in either case on cursory examination, and both exposures are much obscured by the surrounding cotton soil.

Shellugi chert bed.

Amongst the intertrappean beds we may well include cherty beds, which are so common in the corresponding formations in Central India and characteristic of them. Only one bed of chert was met with throughout the region now under consideration; this occurs about seven miles north-east of Talikot, and one mile west of the village of Shellugi, and occupies the highest ground in the neighbourhood, stretching about three miles north and south, with a maximum width east and west of about a mile or a trifle over. The chert bed forms a small plateau of irregular outline, in great part thickly covered up with cotton soil. This bed is best seen at its southern end, where a huge *nim* or *margosa* tree forms a landmark, conspicuous for many miles around. The bed, as here seen, seems only about one

* There are other iron-clay deposits occurring here and there over the trap area which are very likely merely results of subaërial atmospheric action, and which will be described when treating of subaërial deposits. From their position they might, however, be regarded as intertrappean relics analogous to the quartzite gravels above described.

yard in thickness (possibly a little more), and is not thoroughly continuous, but rather an assemblage of large blocks lying near each other at the same level. The chert is of variable color, from mottled whitish-grey to yellowish-brown. Some blocks show a more chalcedonic character, with patches of delicate whitish-blue or peach color. The bed seems entirely broken up by atmospheric agencies, and the ground is covered thickly with chert débris to considerable distances beyond the real limits of the plateau.

No trace of organic remains could be discovered by the naked eye, but from the truly bedded character of the bed at Bantanoor the subaqueous origin of the chert cannot be doubted, and it is more than probable that fossils may yet be found imbedded in it.*

The degradation of chert beds of very similar character has contributed to the formation of the large beds of chert gravel to be seen in the old alluvium of the Krishna and Bhima rivers.

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* The occurrence of blocks of highly cherty limestone lying detached on the surface of the trap on Ingleswara hill near Bágewári, 25 miles west-by-north of Shellugi hill, was noted by Captain Newbold (Notes between Masulipatam and Goa, J.A.S.B. xiii, p. 1002,) who also pointed out its resemblance to the fresh-water limestones of Nirmal, Munapalle, and Kulkonda, between Gulbarga and Mactul (Muctul).

CHAPTER VIII.

THE DECCAN TRAP IRON-CLAY (LATERITE) FORMATION.

The name laterite should be restricted

The group of argillo-ferruginous rocks, of which so many varieties occur in India, is one of the most difficult to deal with, because so much confusion has been introduced by the indiscriminate use of the term "laterite," a term good and useful in itself, but which, in conformity with the rules of scientific nomenclature, should be rigidly restricted to rocks of the same origin as those to which the term was first applied by Dr. Buchanan, its inventor. Doubts exist, however, as to what was the nature of the rock he was treating of when he proposed the name in question. He describes it as "diffused in immense masses without any appearance of stratification," and "placed over the granite that forms the basin of Malayala"—Malayala meaning the country in which the Malayalam language is spoken, and including Travancore, Cochin, and Malabar. He does not localize his description more closely when treating of the subject in Chapter XII of his journey through Mysore, Malabar, and Canara,* a chapter which is headed "Through Panyain (Panyani) and Central Malabar." The laterite of Malayala, Canara, and the Konkan is, from its very position, presumably of sedimentary (marine) origin, and this view is greatly strengthened by the fact that not only are proofs found in parts of the formation itself† of such sedimentary origin, but also by the fact that, on the opposite side of the peninsula, beds occupying the same relative position with regard to the present coast line (and which from their geographical position may safely be regarded as mere extensions

to certain sedimentary deposits.

* Published in London, 1807, 3 vols., 4to.

† e. g., at Cottayam in Travancore,—see Memoirs, Geological Survey of India, Vol. IV, p. 258, note.

of the western coast laterite), are in many places of the most unquestionable sedimentary origin. Although so much evidence exists in favor of the sedimentary origin of the fringe of ferruginous deposits which surround the southern part of the Indian peninsula, it is impossible to be quite certain as to the nature of the rock Dr. Buchanan named "laterite," till the Malayalam country shall have been examined by some competent geologist and that question set at rest. Till that point is definitively settled, the name laterite can only be provisionally employed, and should be applied only to rocks of sedimentary origin. Such being the case, a very large proportion of the argillo-ferruginous rocks in the South Mahratta Country and South-Western Deccan, now regarded as not of sedimentary origin, though lateritoid in character, can no longer be treated of under the old name of laterite, but the term will be retained for certain petrologically similar rocks in the Southern Konkan, which, from their geographical situation, may reasonably be supposed to be of sedimentary origin, and possibly also to belong to a later geological period. For the others a new name must be found, and it will be simplest to revive the designation given by the late Dr. Voysey to the corresponding rocks in the centre of the Deccan at and around Bidar, *viz.*, "the iron-clay,"—a name at once brief and lithologically correct in its description of the rocks in question. Dr. Voysey was the first to point out the great probability of the "iron-clay" having originated by decomposition of a truly trappean rock—a view which the facts now to be given appear to prove conclusively true.

Certain other argillo-ferruginous rocks, apparently of lacustrine origin, which occur in the lower valleys of the Malprabha and Ghatprabha rivers, will also be classed as laterites.

Among the iron-clays it becomes very important, though by no means always easy, to distinguish two classes,—1*stly*, those which must be regarded as members of the Deccan trap series much altered from their pristine condition by subaërial agencies; and 2*ndly*, those which

are mere subaërial (pluvial) re-aggregations of débris of rocks of the first class. The age of the rocks of the second class can only be determined as subsequent to the time when the country had acquired very nearly its present features, as already pointed out when describing the Deccan trap in the ghât region (p. 174): the examination of the several iron-clay formations there recurring only yielded evidence of negative character, and therefore insufficient to determine positively their origin. No doubt remains, however, that they are not in their original condition, but have been greatly altered by subsequent agencies of a subaërial nature, and it only remains to be asked whether the rocks in question represent altered lava flows, or altered sedimentary associated rocks, or both in parts.

The correct reply to this question appears to be that they represent both kinds of rocks, but that the iron-clays formed by alteration of lava beds predominate vastly. Only one case was met with showing strong evidence of the original sedimentary origin of an iron-clay: this will be mentioned further on.

Numerous sections occur in which the passage by subaërial decomposition of the trappean rocks into argillo-ferruginous rocks may be seen. Some of the best are on the great military roads crossing the mountains by the Amboli and Phonda Ghâts, where the decomposing rocks have been cut into to some depth. It will be there seen that the basaltic rocks graduate into a moderately hard yellowish brown or brown earthy mass which encloses many nuclei of the original rocks in various stages of decomposition. The upper parts of the decomposed mass from which the nuclei have disappeared have undergone a process of concretional solidification from the infiltration of surface waters holding iron in solution, and are assuming the ordinary lateritoid appearance and reddish color. This decomposition appears to be mainly due to the action of water detained in the horizontal joints of the rock, for in those flows in which columnar cleavage has been developed, and in which but few

horizontal joints occur, very little weathering has taken place, the water being able to percolate freely downward instead of being lodged and retained for lengthened periods.

This decomposition into argillo-ferruginous masses may, under favorable circumstances, take place in any rock containing iron.

From the total absence of any indications of sedimentary origin observed in the "summit bed" of the trap series, one is compelled to suppose that it originated by the decomposition of some trappean rock, but it must have been a rock in which no silicious segregations such as geodes were included, for no trace of them has been observed to occur in any part of the summit bed. Such a variety of trap is very rare, but not absolutely unknown, and it is conceivable that from the fact of the summit bed having concluded the series of outpourings and not having been covered up by later formations, the waters which percolated it did not contain silica in suitable quantity to give rise to the formation of siliceous amygdaloids in the unweathered flow.

The underlying trap into which the summit bed now-a-days is seen to graduate at the principal sections, as Sámángarh, Wallabgarh, &c. (see page 181), is a very clay-like rock without any enclosed minerals, and resembling in color and fineness of texture many of the purple, brown, reddish amygdaloid beds occurring so largely elsewhere, but differing in the total absence of vesicular cavities, whether empty or filled up. There is no obvious reason why the uppermost flow may not have been of the same homogeneous clayey character, though with a larger admixture of iron in its constitution. If such a rock be granted, no difficulty remains in supposing that the formation of the iron clay by percolation of water of similar character had occurred at different periods during the trappean era, and given rise to the formation of similar rocks, as seen now in the several series of lower-lying iron clays (see page 209). None of these, however, approach the summit bed flow in magnitude or extent.

The summit iron-clay beds.

As already mentioned in Chapter VII, the iron-clay forms a well-defined and very conspicuous capping on the summits of the highest ridges and peaks in the Belgaum and South Kolhapur sections of the Sahyádri, or Western Ghât, mountains, and the fact of many of these very peaks and ridges having been chosen to be fortified and converted into the strongholds of the old Mahratta Chiefs was pointed out specially. In addition to the peaks and ridges there named, many others occur on which this capping of argillo-ferruginous rocks forms very marked and striking features. The most important of these cappings which may be regarded as the remains of a once widely-extended bed will be enumerated below. Some form outliers on the older rocks where the latter are of great elevation and stand up above the general mass of the trap flows, but are overlapped by the ferruginous beds.

Outliers of the summit bed.

The principal outliers of the summit bed, counting them from the southern extremity of the trap area northward, are:—

1. The Jamboti ridge.
2. Bailur (Byloor) trigonometrical station: Peak 3491′ high.
3. The Kurleh and Buknur hills, south-west of Belgaum.
4. Kálánandigarh and Mátungi, and the high spur connecting them with
5. Máhipálgarh ridge.
6. Gandharvagarh ridge.
7. Wágbud and Kásarsadda plateau west and south-west of Chándgarh.
8. The high ridge between the waters of the Ghatprabha and Haran Káshi south of Amboli, and also from a little north of the Belgaum and Vingorla road north-east-by-north to the Khanapore trigonometrical station hill near Azra (Ajra of map). Several outliers occur also along the spur running from west to east towards Naisri. This spur is connected with the Sámángarh knot of hills and its several outliers of the summit bed.
9. The group of high spurs north-west of Kittura (Kittoora), from the most southerly of which starts the great Budhargarh ridge with its various branches, on which the summit bed is very typically exposed.
10. The high ridge dividing the valleys of the Yed and Dudh Gunga rivers, including the well-marked plateau north of Paia (Pyah).

11. The "South Peak Station" mountain between the two upper branches of the Dudh-Gunga river.

12. The plateau ridge between the valleys of the Dudh-Gunga and Bhogavatti rivers.

13. The ridge north of the Bhogavatti valley.

Far away from the ghats but connected with the eastward extension of the great Bhudhargarh ridge are

14. The Wallabgarh outlier and

15. The Bagéd Gudda outliers, two in number; on the eastern one a trigonometrical station 2,667' high.

16. The group of outliers west and south-west of Gokák, two of which are overlaps on to the Kaládgi quartzites.

17. The Paizargarh group of four small outliers, with a fifth forming the summit of Hoolee-Gurkeit hill, three miles to the east.

18. Arlehatti outlier, four miles west of Páchápur (Padshapoor), rests directly on the quartzites, as do also in part

19. The Rámdurg outliers, four in number, lying 10 miles north of Belgaum. The most south-westerly of these rests partly on the trap, partly on the quartzites.

20. Yellurgarh, seven miles south of Belgaum, shows the last of the summit bed outliers which there rests on trap. The summit is 3,365' high.

There are several other outlying patches of similar ferrugino-argillaceous rocks in the more eastern parts of the trap area, but they are too distant to be safely correlated with the summit bed.

Sections mostly obscure.

Numerous though the outliers of the summit bed are, they yet present very few satisfactory sections; not one indeed could be considered really good for the purpose of studying the origin of this peculiar rock and its relation to the underlying trap-flows. Owing to the superior hardness of the highly ferruginous summit bed and the more rapid weathering away of the underlying beds, the surface of the latter is very generally covered by talus or by great fallen masses of the upper beds. In other sections a quasi-stalactitic ferruginous rain-wash frequently renders the surface appearance of inaccessible cliffs doubtful. The presence of delicate grey, orange, pale-pink, and flesh-colored lichens in very large numbers in many cases changes the colors of the scarp faces very greatly, so that it is only on close inspection that the true colors can be made out.

The four best sections met with were those on Kálánandigarh, Sámángarh, Wallabgarh, and Paizargarh.

Kálanandigarh section.

The first of these is best seen on the path up to the north gate of the old Mahratta fort which gives its name to the hill. The upper 100 feet of the hill consists of mottled purplish and white or purplish clayey rock (clayey trap?) which passes up without any sudden change into the compact lateritoid mass.* The hill side becomes scarped as soon as the level of the summit bed is attained, but the exact point of junction of the two rocks is not clear from the presence of vegetation and buildings. The thickness of the summit bed is about 30′ vertical, or more.

Sámángarh section.

In the Sámángarh section the rocks are most clearly exposed along the steep path leading from the little village of Chonchwadi† up to the pagoda on the western plateau. The same condition of things exists here as at Kálánandigarh; the clayey under-rock acquires more and more iron as it is followed upward and passes into the "iron-clay." The clayey bed is more variegated in its colors, however, at Sámángarh, shades of orange, pink, and brown occurring with the purple.

Wallabgarh section.

At Wallabgarh the clayey under-rock shows a good deal of quasi-vesicular structure in the arrangement of the colors; numerous thin films of white color are seen like little vesicles enclosing darker portions of the general mass, such vesicles being of very various sizes. The predominant colors here are purple and reddish-brown, much flecked with the white vesicle sec-

* Newbold supposed the beautiful lilac color of the lithomargic earth underlying the iron-clay (laterite) of the Bidar plateau to be due to the presence of manganese, a supposition which is probably true.

† Chonchwadi stands in a hollow in the south side of the Sámángarh hill, about 200 feet below the summit. The fort was besieged and taken from the rebels during the outbreak in Sawant Wari and Kolhapur in 1844.

tions. The ferruginous summit bed displays a peculiar structure, for instead of showing the ordinary horizontal or approximately horizontal position of the vesicular cavities in the mass, it is permeated by vertical tubuli running nearly through it. The upper ends of these tubuli are empty for a little distance, giving the surface a pitted appearance, but the tubes are generally filled with lithomargic clay, and have their walls lined with a glaze very like that so frequently met with in the vermicular cavities of ordinary laterites. The tubuli vary in diameter from ¼ to ¾ of an inch, but are generally less than ½ an inch across. Their height depends upon the thickness of the bed, and the glazed sides show much statactitoid waviness of surface. In the lower parts of the bed the tubuli are less distinct. There can be little doubt but that the formation of these tubuli is due to the action of percolating water. This structure is not so commonly met with as the rudely-bedded quasi-stratified forms in which the vesicular and vermicular cavities are rather horizontally disposed.

Tubulated structure of iron-clay.

The section seen in Paizárgarh hill shows a thick-bedded mass of iron-clay with little or no tubulation, resting on a clayey trap (?) of generally grey or purplish color, finely streaked and mottled with reddish-brown, orange or dull yellow. The vesicular markings noticed at Wallabgarh are seen here also, but are much less common.

Paizárgarh section.

A very peculiar pisolitic form of the iron-clay was observed in several places, notably on the Yellurgarh, on Bailur (Byloor) trigonometrical station peak, and on the Kásarsadda ridge south-west of Chándgarh. Where this pisolitic structure supervened, the rock was seen to have a decidedly jaspideous texture and look. The color of this form of iron-clay varies from pale brownish pink to bright or deep-red, or purple, according to the percentage of peroxide of iron included.

Pisolitic iron-clay.

The individual concretions, which vary in diameter from less than $\frac{1}{12}''$ to $\frac{1}{3}''$, but average about $\frac{1}{6}''$, are cemented together by a material generally of much the same mineral character, but occasionally much richer in iron.

Greatest thickness of the iron-clay.

The greatest observed thickness of the summit bed was from 50 to 70 feet; this was on the south scarp of a high peak at the edge of the ghâts, three miles north-east of Sonegarh (Soneghur) in Kolhapur State. The section, a very fine one formed in a recent landslip, was most unfortunately inaccessible. Here, and in many other places, prominent parts of the weathered surface of the rock show a bright red color and shining glazed jaspideous surface. On much-frequented paths knobby pieces of the rock are frequently found to have acquired a high polish from the naked feet of the natives—a state of things which does not render the paths the more practicable for people shod in European fashion. The paths on this and other lateritoid rocks are remarkable for their excessive roughness and lumpiness.

In the extreme north-eastern part of our area the iron-clay reappears, and is largely developed on the high trap plateaux between Gulbarga and Bidar, on which stand the villages of Humnabad, Bara (Burrah) Yekali, Koyer, &c. The average elevation of this region is about 2,000 feet above sea level, and rises at Bidar to 2,359 feet according to Voysey's barometrical observations. This high elevation points to this iron-clay belonging to the summit bed of the ghât region.

The iron-clay occurring at Gopenpully, four miles west of Bara Yekali, was examined by Mr. King, who describes it in his notes as "a highly ferruginous, brown, nodular and concretionary rock, exactly like laterite."

He failed to find any indications of its being of detrital or sedimentary origin. In texture this rock quite agrees with the iron-clay of the ghât region, for it is "a mottled rough clay, pisolitic and full of irregular cavities between the pellets," or else "rudely and irregularly vesicular,

and having larger vermiform and pipe-like hollows ramifying through it, which last are generally rudely vertical." "On the bund of Gopenpully tank and thence through the village and down to the lower plateau leading towards Yekali there are numerous sections exposed of this ferruginous rock. At the surface or towards the top of the cliffs the rock is like the ordinary brown pisolitic laterite. This graduates downwards to a yellower clayey variety with irregular sinuous vermiform cavities, and below this is a purple clayey rock with yellow and brown mottlings. I saw no trace of conglomerate or of detrital matter in the faces of the cliffs. There are, moreover, indications of globular weathering as of trap and of vertical jointing at wide intervals." No signs of bedding exist, except such as are due to the presence of the three not sharply-defined bands of color above described. Mr. King arrived at the conclusion that the iron-clay was the result of decomposition *in situ* of trappean rocks, the same conclusion as forced itself upon me in the Sahyádri mountains. The iron-clay of the Bidar plateaux occupies a position corresponding precisely with that of the "summit bed" in those mountains.

There is a difference in the mineral condition of the iron-clays of the two regions, which is noteworthy,—namely, that in the ghâts the ferruginous constituent of the rock is very largely, mainly indeed, in the condition of hæmatite, the red anhydrous peroxide of iron, while in the Eastern Deccan it consists of limonite, the hydrous or brown peroxide of iron. The color varies accordingly, being red of various shades in the ghát region and brown in the Bidar plateaux. The red color is very conspicuous in the former region, so much so that the native (Mahratta) name is "Tamara Donda," or "the red rock."

Other iron-clay beds.

Beside the great deposit of "lateritoid" iron-clay just described, are others in the ghát region at lower levels, but all apparently of similar origin and presenting no differences recognizable by ordinary inspection. All the peculiar differences of structure noted in the "summit bed" can be paralleled in

some of the lower-lying beds, and nearly all of these occur in or very near to the ghát region, and the most important very close to the watershed, and therefore generally close to the edge of the ghát scarp, more especially in the extreme south corner of the trap area.

At Rám Ghát.

A very extensive show of "lateritoid" iron-clays occurs at and to the east and west of Rám Ghát. The rock there forms a nearly level ridge with a ragged scarped edge and a talus of great fallen masses, which ridge stretches away on the north-east into the high spur west of Hireh (Hebreh), while to the west it joins the Isápur (Eesapoor) plateau north of Párgarh, along the north side of which it forms a very distinct and generally vertical scarp from 30 to 60 feet high. The Rám Ghát bed may possibly belong to the "summit bed," but in all probability it is distinct, for not only does it occur at a considerably lower elevation, but it does not lie in a level plane as does the summit bed. Moreover, it rests in some places direct on a basaltic flow without the intervention of the thick clayey trap so constantly present under the typical outliers of the "summit bed."

At apparently the same level are several ragged-edged plateaux south and west of the high Kasarsadda ridge about the head-waters of the Ghatprabba. To the same set belong the beds occurring on the high ground south-west of Patna and at Kodali (Kohada) on the north side of the great Tillár ravine.

South of the Tillár ravine.

South of the Tillár ravine at Kolik (Koleek), Chigoli (Cheegooleh), Kunkumbeh (Koonkoombeh), Holund, and stretching out westward towards Chorleh and to the extreme western points of the Sadda (Suda Ft.) spur, overlooking Goa, are continuous sheets of the iron-clay belonging to a bed or beds occurring very much at one and the same level. Southward past the top of the Parwár Ghát these sheets of iron-clays join those occurring at

foot of the great Jamboti ridge, and pass south-eastward forming, near Ambgaon and Chapoli (Champolee), a well-defined plateau capping the extreme southern promontory of the great Deccan trap area overlooking the deep and romantic ravine of the Mahádayi (Maadwee) river, (see page 3). As seen from the edge of this ravine, the iron-clay beds appear to be represented on its southern side by a similar set forming a plateau around Gauli (Gowulee). To the northward of Rám Ghát this set, which may for convenience be called the "watershed series," is represented in the plateaux near the source of the Ghatprabha already alluded to, and also in the valley of the Harankashi river near Mahadeogarh and Narayangarh (Narraingurh).

Caves in the iron-clay.

Two remarkable caves were observed in these lower iron-clays, one a little to the west of Sadda (Suda), the other about a mile to the north-north-west of Holund. Both occur below the surface of wide level spreads of rock, and present no other openings but large rudely circular holes 12 to 15 feet in diameter and about as deep. Neither is accessible without ladders, owing to the "oubliette" character of the mouth, and torches are also required, for want of which I was unable to explore them, as time did not admit of my re-visiting either place. According to the villagers, both are frequently tenanted by wild beasts, bears or tigers; the Sadda cave indeed was said to be a permanent tigers' den, and my guides so greatly objected to attempting any descent into it, that it looked as if they had told the truth. It has two openings at no great distance apart, and is said to be very extensive. These caves have in all probability other lateral exits for the water which drains into them. They are probably due to the action of subterraneous streams formed during the tremendous bursts of the south-west monsoon. None of the openings seen had the character of swallow-holes, but seemed due to the roof of the subterranean passage having fallen in locally.

Iron-clay of sedimentary origin.

The only case in which evidence was obtained showing that an iron-clay bed was of sedimentary origin was noted at Chapoli (Champolee) on the north side of the Mahádayi ravine. The iron-clay there forms a very well defined plateau on the high spur south of the village. The sides, which are well scarped, show a thickness of from 15 to 20 feet vertical of the tubulated variety of iron-clay, the tubulation being very strongly and clearly developed. A number of quartz pebbles were here found imbedded in the clayey mass, from which it may be inferred that this iron-clay represents, either wholly or in part, an altered intertrappean pebbly clay of the kind described in various typical intertrappean beds.

Along the south side of the great Jamboti ridge, on the path leading from Chikleh (Cheekleh) to Amoteh, are several alternations of iron-clay and basalt at different levels in the jungle, the former apparently forming distinct terraces which might correspond to altered trap-flows or intertrappean beds. Unfortunately no sections were found *en passant* by which it could be decided whether these terraces did really represent distinct formations.

Lower-lying iron-clay plateaux.

Three sets of small iron-clay plateaux occupying rather lower levels than those of the watershed series occur respectively in the valleys of the Márkándeya, Támbraparni, and Ghatprabha rivers. Those of the first and last sets form small groups of strikingly flat-topped hills, in the former case near Unchgaon (Oonchgaon) on the Belgaum-Vingorla road, in the last to the southward of Arkur; all these hills are nearly perfectly bare of vegetation.*

Similar minor plateaux occupying the same relative level occur in the upper parts of the valleys of all the other rivers flowing from the ghâts,

* They were only looked at most cursorily, and no information was gained as to what the iron-clay may have been derived from.

but they are less well defined than those just mentioned, and very much more obscured by jungle. To have visited them all would have required several months' more time than could be given to the ghát region.

Sub-aërial agglomerates.

Much iron-clay that is not referable to any of the sets of beds named, and mostly lying at yet lower levels, occurs scattered over the country. Much of this more recent rock is unquestionably a sub-aërial agglomeration of lumps of older iron-clay beds broken down by weathering and mixed up with other ferruginous and clayey materials of pluvial collection and cemented in part or wholly by further deposition of ferruginous matter. At times rocks of this origin are difficult to distinguish from the older form, but generally they show their true nature by their lying confusedly and irregularly on the uneven surface.

Iron-clay at Belgaum.

A deposit of iron-clay of which the origin is not quite clear and the position relative to the beds before described is obscure, is that met with at Belgaum. The iron-clay there occupies a deep bay or hollow on the east side of the basaltic rise, on which the new European barracks have been built. The basaltic high ground here forms an angle, the apex of which lies north-west of the town, and in that angle the iron-clay is most largely exposed in two sections, one in the new well sunk in the soldiers' garden, the other in a deep well-like pit whence road metal is extracted. In the former section, the iron-clay had not been pierced at a depth of from 35 to 40 feet, and in the latter the thickness exposed exceeded (in 1872) a depth of 50 feet vertical, and yet the underlying trap rock was not exposed. In the well section the rock is not so well seen from the smaller size of the opening, but in the quarry the unweathered surface of the walls displays the rock to great advantage. The rock is very different in character from that seen in the sections of the "summit bed" or "watershed" series, traversed by vesicular and vermicular cavities.

Instead of a rock vertically tubulated or nearly horizontally disposed, this particular iron-clay consists of an aggregate of nodular fragments in a quasi-conglomeratic mass, the quasi-pebbles being arranged in rudely horizontal lines. Beyond the latter there are no traces of bedding, but the downward decrement of the iron percentage in the rock is *very* clearly exhibited. No traces of any enclosed mineral of pre-trappean origin could be found in either deep section nor in any of the numerous superficial gullies and cuttings to be seen in and around the cantonment and town. The whole formation presents the appearance of being a sub-aërial accumulation of pluvial detritus of older iron-clay beds. The iron-clay which is exposed in ballast-pits close to the tank north of the pit is quite different in character, being truly vesicular and far more ferruginous. The stones used for the walls of the pit are also of the same character, and were probably quarried in great part during the construction of the moat.

The iron-clay exposed in the old bowrie close to the post office and Idgah is also of the vesicular kind. No sections were found showing the relations between the vesicular iron-clay of the pit and the nodular rock exposed in the hollow east of the cantonment and church hill. Should any ever be made, I expect the nodular quasi-conglomeratic variety will turn out to be the newer of the two. Both varieties are much covered up by thick red sandy soil, and the boundaries of the iron-clay and underlying traps are thereby much obscured. This red soil is so largely developed over both iron-clay and trap and gneiss, and in places so much charged with the nodular pieces of iron-clay, that it is often impossible to draw any line showing the true boundary of the trap and older iron-clay and gneiss; hence the tract where this *red iron-clay soil* occurs has been shown in the traps as a sub-aërial deposit. The same thing was found to be necessary in mapping the valleys of the Belgaum nullah, east of Belgaum, and the Márkándeya (Markundee) river north of that town.

The iron-clay beds at Managoli (Mungole) and Mutgi (Mutge) in the Bágewári Taluq do not come within the limits of this report and were not visited, though they are close to the boundary of the area surveyed. Still further east is another outlier of what may be the Deccan iron-clay in the shape of a small capping to the trap at the summit of the Nagurbetta, a sharp-pointed conical hill about three and a half miles north-north-west of Nalutwar in the Kaládgi district. The iron-clay is here seen to rest conformably on the Deccan trap, the flows of which are horizontal, or very nearly so. This capping of iron-clay is about 200 yards in length and rudely elliptical in plan. It is of deep yellowish brown color and more compact in structure than the ordinary iron-clay in the ghát region, or than the common laterite conglomerate of the Carnatic. The texture also is more porcelanous, and in some parts almost jaspery; in others, however, quite earthy and dull; the vermicular cavities so characteristic both of the coast laterite and the typical iron-clay are also absent, but still, when regarded as a whole, there is a decided resemblance, especially where weathering has taken place. No trace of any organism was found in this rock, but in several places it showed polished striations on different exposed surfaces much resembling those of a "slickenside." Similar markings are occasionally to be seen in very compact varieties of the truly sedimentary laterite in the Carnatic, *e. g.*, in the south side of the great Sembaram Pakkam (Chumbrumbaucum) tank in the Madras district.

Iron-clay on Nagurbetta.

Another patch of compact iron-clay lies about a mile south of Buntanoor (an outlying village of the Nizam's territory, some seven miles north-east-by-north of Talikot (Sheet 59, S. W., $\frac{1}{4}$). Here numerous blocks of a more typical iron-clay conglomerate of the usual deep brownish red color occur on the same level with, and mixed up with numerous blocks of whitish chert. Owing to the extent of soil covering the knoll on which these rocks are seen, it is difficult to decide which rock may be the one

At Buntanoor.

truly in *situ*. Whichever it may be, the other blocks are probably the ruins of an overlying bed which have subsided gradually into their present position. I was quite unable to satisfy myself which might be the rock really *in situ*, but it is very unlikely that two such widely-different rocks could have been deposited in juxtaposition as the blocks now appear. The iron-clay blocks, masses of 2 to 3 tons weight, show an approach to vermicular structure. The knoll occupied by this mixture of blocks is of small size, hardly more than an acre in superficial area.

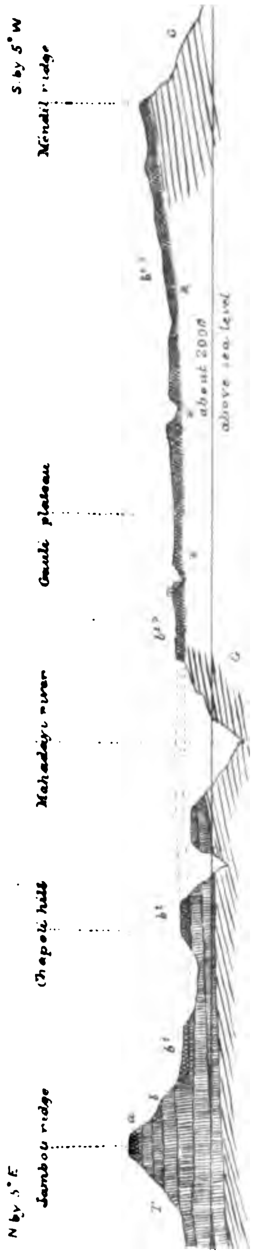
To the south of this knoll extends a plateau occupiod by chert blocks, but the whole is too much covered with black soil to give any good sections.

Iron-clay formations outside of the Trap Area.

Beds of iron-clay, very strongly resembling the typical beds above described, or indeed identical in lithological characters, were met with at several points outside the limits of the trap area; but it is probable that, in most cases, they were once continuous with iron-clay beds unquestionably belonging to the Deccan trap series.

Certain outliers of the "summit bed" iron-clay, which are manifestly mere outliers of that bed overlapping on to elevated parts of the Kaládgi quartzite series, are not here included.

It was pointed out, when speaking of the iron-clay beds occurring on the south side of the Tillár ravine and the north side of the great Mahádavi ravine (page 211), that they appear to the eye to be again represented by the beds forming the Gauli (Gowulee) plateau south of that ravine. A serious difficulty exists, however, in correlating the two formations, from the fact that the iron-clay of the Gauli plateau rests upon, and passes down into, the weathered surface of the underlying gneissic rocks. No positive trace of the Deccan trap could be found after a very close and laborious search, though, when seen from the north from various points along the lofty Jamboti ridges or from the lower iron-



Section across Gauli plateau.

a. High-level iron-clay "Summit bed." b and b1. Other iron-clays. T. Deccan trap. G. Gneissic series. * Sub-rock, unknown.

clay terraces of Ambgaon* and Chapoli (Champolee of map), the Gauli plateau most strongly resembles a normal iron-clay-capped trap area.

This Gauli plateau, which is of considerable extent, but rather irregular shape, stretches southward upon the high ridge which extends eastward from the Páhldy (trigonometrical station) peak,† and forms the boundary between the Belgaum and South Canara districts.

The whole aspect of this plateau and its position relative to the iron-clay terraces north of the great ravine are strongly suggestive of their having once been continuous, and the sketch section given herewith strengthens that idea, which forced itself very strongly upon my mind when on the spot. The chief difficulties to be explained away before that idea can be accepted are—1*stly*, the absence of traces of the Deccan trap, and 2*ndly*, the absence of any distinction between such parts

* Ambgaon lies nearly a mile further S. S. E. than shown in the map.

† Locally known as the Darshin Dongar. The western part of the ridge in question, as seen from Bimgarh, is shown in Plate III. The iron-clay beds there rest upon the crystalline magnesian limestone beds, forming the remarkable cliffs shown in the view.

of the iron-clay as may be supposed to be of trappean, and such as are unquestionably of gneissic, origin.

As already mentioned above, the iron-clay plateau extends from Gauli southward up the slope of the eastern spur of the Darshin Dongar (Páhldy trigonometrical station), and the iron-clay is continued along the ridge to the very summit of the mountain, where it is cut off short by a sudden scarp, on the edge of which stands the trigonometrical survey cairn. This scarp trends away from the summit to the east on both sides of the ridge, the northern scarp joining the west scarp of the main mass of the Gauli plateau, and the southern one running eastward south of Meindil (Meindool of map), and terminating in a bluff to the east of Dehgaon.

The examination of the country did not extend southward of this ridge, and I cannot say if this iron-clay is represented at corresponding levels on the hills in the North Canara district. It is probable that it does not re-appear, or only in a much smaller degree, for there is a decided change in the general outline of the hills further south.

Outliers of the same iron-clay show on the summit of the hills extending eastward towards Siruli (Seeroolee of map).

From the Páhldy trigonometrical station the iron-clay plateau dips visibly at a low angle, 3° to 4° perhaps, to the north and north-east by north, an inclination coinciding very nearly with that of an ideal extension of the trap-flows from the north side of the Máhadayi ravine to the Páhldy ridge, a fact strongly confirmatory of the idea that the Gauli iron-clay plateau is an altered trap formation.

No external distinction traceable.

No external distinction could be traced between the iron-clay formed by decomposition in situ of the gneiss and of the great trap-flows; a difference must doubtless exist, which will be detected, perhaps, by closer study than was feasible while making a rapid primary survey of so rugged a country. The very process which gives rise to the formation of this remarkable subaërial rock, a process which is still in full activity, namely, the per-

colation of water, must tend to diminish daily whatever difference originally existed between the products of the two several kinds of rock affected.

As above mentioned, the passage downward of the base of the iron-clay into gneiss is to be seen very clearly in various sections in the scarped edges of the iron-clay plateau, also in the beds of some nullahs, *e. g.*, the Gauli nullah and the stream flowing westward from Talewári (Tullwaree). In the latter the descent from the pure iron-clay into decomposing gneiss is very clear, the quartzose laminæ of the latter remaining in situ after the softer parts have all been replaced by the clayey mass, and standing up in the latter for a distance of many inches. The undecomposed gneiss is not seen in any of these sections.

In the small stream rising south-westward of Meindil (Meindool) south of Talewári, the passage of a micaceous schistose gneiss upwards into iron-clay is very clear, as the stages of decomposition of the older rock are well exposed in the bank of the stream.

The iron-clay is not unfrequently a breccia in structure, owing to the presence of numerous small angular fragments of white vein quartz, which are very frequently seen in similar iron-clays far away from the gneiss rocks, and about the wholly trappean origin of which there can be no doubt.

Origin of enclosed quartz fragments.

The source of these quartz fragments has yet to be traced; they are not derived from the trap rocks themselves, as the latter do not contain quartz in their composition in this form, nor are they derived from the breaking up of amygdaloids, nor is it easy to see how they could have been derived from a quartz formed during the decomposition of the trap, which would show a nodular, if not positively concretionary, structure. No trace of such structure could be seen on any of a very large number of the quartz fragments and splinters in the breccias.

Absence of geodic quartz.

The exceeding rarity of geodic quartz in these subaërial iron-clays is also a difficulty of which I cannot offer any solution. Common as are the amygdaloid geodes

in nearly all the trap rocks, only one single specimen of agate was found in this iron-clay. This was part of a small geode which was picked up out of a crumbling mass of iron clay fallen from the roof of the Bárah Pir Cave at Talewári.

This fragment of agate and the presence of pebbles of quartz, gneiss and quartzite exposed at the bottom of the cave by the action of a small stream which flows through it during the rainy season, are additional evidences in favor of the trappean origin of the upper part of the Gauli iron-clay plateau. The agate speaks for itself, and the pebbles indicate the presence of a small inter- or infra-trappean sedimentary deposit like those of which so many exist between the bottom flows of the Deccan trap, or between the trap and the older underlying rocks.

The Bárah Pir Cave.

The Bárah Pir (twelve saints) already mentioned consists of one fine large irregularly-shaped chamber measuring between 45 and 50 yards in greatest length, by perhaps 20 in greatest width, and from 10 to 15 feet in height. The entrance is large, and faces eastward.

There is an entire absence of stalactites and stalagmite, and the walled sides show the structure of the rock very well. The rock is a tubulated iron-clay of pale color, and but moderately ferruginous. A small stream which enters the south-western corner of the cave just below the roof, partly through the roof in fact, has washed in a small number of pebbles of quartz, gneiss and quartzite. The cave is in a small hill rising from an extensive, but rugged and uneven, sheet of the iron-clays, to the west of the hamlet of Talewári.

Bidarbhávi hill.

A small but exceedingly well-marked iron-clay plateau, twenty to thirty feet thick, forms an outlier on the top of the Bidarbhávi (Beedurbhawee) hill, five miles south-east of the Yellurgarh; but under circumstances rendering it very difficult to correlate it with any of the iron-clays occurring to the west or north-west. It shows much vertically tubular structure, and the amount of iron con-

tained decreases steadily with the depth. The rock is also very distinctly bedded. Below the base of the scarp no rock is satisfactorily seen *in situ;* but the sides of the hill are covered with iron-clay débris, or masses doubtfully in place. Nor is the gneiss exposed for some distance from the base of the hill, and the nearest visible portion of Deccan trap is the south spur of Yellurgarh hill, fully three and a half miles to the north-west. From its external resemblance and its level, as compared with Yellurgarh, it is not unlikely that it represents an altered inter-trappean or infra-trappean deposit.

Outliers of the iron-clay.

Beyond the limits of the trap area in Kaládghi district are two outliers of iron-clay which certainly bear a very striking resemblance to typical exposures of it, and the probability of their being connected with the trappean series is rendered more probable by the occurrence of two small patches of iron-clay of identical appearance to one of the two first-named, and resting on the Deccan trap. The two first-named outliers occur, the one near Bellegunti, three miles south-west of Kerur (Kehroor) in Bádámi Taluq, while the other forms a very conspicuous truncated cone capping a quartzite plateau five miles south-east of Kerur. The two outliers resting on trap occur a mile south-east of Batkurki. In the case of the Hulikeri (Hoolikeree) hill south-east of Kerur, the iron-clay is a very distinctly vertically tubulated variety, but both the Bellegunti and Batkurki patches consist of vesicular and vermicularly tubulated iron-clay.

CHAPTER IX.

THE RATNÁGIRI PLANT BEDS.

Resting upon the denuded surface of the Deccan trap on the coast of the Konkan at Ratnágiri is a bed of white clay containing the remains of plants, partly converted into lignite,—which there is good reason to regard as the representatives of the lignitiferous beds discovered in Travancore State by the late Lieutenant-General Cullen. The grounds on which the two formations are viewed as contemporaneous are the similarity of geographical position, and the similarity, if not identity, of the lignites and fossil resins found in both places.

The Travancore lignite beds underlie the local laterite which General Cullen considered to be a rock formed of the detritus of the metamorphic rocks forming the Southern Ghâts—an opinion that is confirmed by my having myself found laterite at Cottayam in Travancore which was a true clayey conglomerate.

The Ratnágiri beds are described by Mr. C. J. Wilkinson, late of the Geological Survey of India, in his Sketch of the Geological Structure of the Southern Konkan,* as "a thickness of a few feet of white clay" seen resting "on the trap in well and other sections," "imbedding fruits and containing thin carbonaceous seams composed for the most part of leaves." He adds—"This is separated from the soft laterite above by a ferruginous band about an inch thick, having much the appearance of hæmatite. It is vesicular, the cavities being filled by quartz, &c."

Dr. Carter, by whom these Ratnágiri clays were considered to be identical with the Travancore beds, mentions in his Summary of the Geology of India† that blue clay has also been found at Ratnágiri.

* Records of the Geological Survey of India, Vol. IV, pt. 2, 1871, p. 44.

† Published in the Geological papers on Western India, Bombay, 1857, p. 722, note.

The Travancore beds consist of blue clays with intercalated lignites and mineral resin (in olive-brown earth) resting upon blue-green gritty argillaceous limestone, containing *Orbitolites* (*malabarica*) and shells whose unquestionably Eocene character was pointed out by Dr. Carter. Some of these shells, as *Strombus Fortisi*, *Cerithium rude*, *Ranella Bufo*, *Cassis sculpta*, *Voluta jugosa*, *Conus catenulatus*, and *C. marginatus* occur in the Eocene beds in Sind and Cutch, and, with the exception of the first, are figured in Colonel Grant's paper on the Geology of Cutch.*

No mention is made either by Dr. Carter, or General Cullen, or Mr. Wilkinson of the nature of the fruits and leaves either from Travancore or from Ratnágiri; they occur, therefore, probably in too imperfect a condition to be determinable.

It is highly desirable that more information should be obtained about this very interesting (Eocene?) formation, and further researches by the residents at Ratnágiri and by others in other parts of the South Konkan are earnestly invited.

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* See Memoir to illustrate Geological Map of Cutch by Captain C. W. Grant, Bombay Engineers, Transactions of the Geological Society of London (Second Series), Vol. V, page 289, or the reprint in Dr. Carter's Geological papers on Western India, p. 408. See also D'Archiac and Haime's 'Description des animaux fossiles du groupe nummulitique de l'Inde,' in which most of the species named above are well figured.

CHAPTER X.

Later Tertiary and Recent Alluvial Deposits.

Under this heading five groups of formations have to be considered; the *first* is the Konkan laterite, an argillo-ferruginous deposit, supposed to be of sedimentary origin; the *second* group includes a series of rocks of sedimentary origin, in which no fossils have hetherto been found, but which, from their mode of occurrence and topographical position, are supposed to be the remains of ancient fresh-water lakes. The age of these is as yet undetermined, but they are certainly older than the *fourth* group, which embraces the alluvial deposits of the existing rivers, and probably also older than the *third* group, which is formed by an ossiferous deposit of fluviatile or fluvio-lacustrine origin of great interest, containing mammalian and other fossils; of the former of which at least one species is extinct. The *fourth* group includes both the older and newer river alluvia, which at present can only be recognized by the respective levels at which they occur, as no organic remains were found in the high level older alluvia. The position occupied by the latter is of itself enough to prove that circumstances have changed the face of the country considerably since they were deposited. The *fifth* group includes the older and newer marine alluvia of the Konkan coast.

1.—The Konkan Laterite.

The reasons for considering this argillo-ferruginous formation as of different origin from the Deccan iron-clay, which have already been given at pages 200 and 201, are the vast difference in the geographical positions occupied by the two formations, and the presumption, based on analogy of position of the Konkan laterite with that of the Malabar and Travancore laterite, that the former is of sedimentary, and probably of marine, origin, the Deccan iron-clay being regarded as a result of the alteration, by subaërial agency, of a volcanic rock. Evidence is wanted to confirm the

second reason, but no doubt appertains to the first. It is quite clear that this Konkan laterite cannot be the equivalent in age of the "summit bed" iron-clay which caps all the high peaks and ridges of the Sahyádri mountains in the Belgaum and South Kolhápur countries, even supposing (as was done by Dr. Carter in his Summary of the Geology of India, page 744), that the low level laterite represents an altered volcanic rock.

There is no reason for supposing that the iron-clay formation did not extend far to the westward of the present western edge of the highland region, possibly across or even beyond what is now the Konkan lowland, and that the iron-clay was not denuded away by the same agencies which cut away some 2,000 feet or more of the underlying trappean rocks. The Konkan laterite, if an altered trap-flow, as supposed by Dr. Carter, is either vastly older than the "summit bed" iron clay, for it belongs to the very base of the Deccan trap series, or if younger it must be younger by the whole of the period occupied in the destruction of the more than 2,000 feet of trappean rocks shown to have been denuded away after the conclusion of the trap period, and formation of the summit-bed, whatever its origin may have been.* The formation of the Konkan laterite and summit-bed cannot have been simultaneous, or else there would be evidence of a great break, and consequently great unconformity, between the summit bed and the upper basaltic flows, for the surface of the latter could not have remained untouched by denudation during the period in which the great scarp was being formed, and the summit would not have occupied the level surface it now does. The fact that the Konkan laterite lies unconformably on the Deccan trap (see section 6, Plate VIII) militates strongly against the idea of the laterite having been formed by alteration of a trap-flow in situ; moreover, there are, underlying the laterite at Ratnágiri, certain clays (described in the last chapter) containing lignite

* There is not a tittle of evidence of any outpouring of the Deccan traps having taken place subsequent to the close of the Deccan period, which was long anterior to the completion of the denudation of the Konkan area.

and resin, and some plant remains, which are all but proven to be of Eocene age. Whether these clays and the laterite are conformable (which is improbable) or not, the total change in the character of the two deposits indicates a considerable interval of time and most likely a positive break between the two. The intercalation, however, of the Eocene (?) lignitiferous clays between the Deccan trap, generally regarded as of upper cretaceous age, and the laterite, is a clear proof of a great break between them. This, added to the evidence deduced from the geographical position of the Konkan, demonstrates that the Konkan laterite cannot be included in the Deccan trap series, but that it must be much younger.

Mr. C. J. Wilkinson, by whom the Konkan was geologically surveyed, offers no opinion in his notes on the subject of the origin of the laterite; he contents himself with describing the rock and the peculiar features of the country attributable to its presence. He says: "When the laterite is present, it gives a monotonous aspect to the country, forming an undulating, and in many places quite flat, plateau, the surface of which is a sheet of rock, black and slag-like externally. This laterite plateau, which has a general elevation of between two and three hundred feet, has a bare, black appearance, supporting no vegetation except scanty grass, and stunted trees here and there. There are places where the rock has been denuded, and here, owing to the presence of thicker soil, the ground can be cultivated.

"It is cut through by numerous rivers, the largest of which rise in "the Ghâts, and after flowing through comparatively open trap country, "enter the laterite through deep ravines which widen toward the sea, the "rivers becoming broad tidal creeks. In the ravines along the banks of "the rivers, villages are generally situated, and every available spot of the "rich alluvial soil is cultivated for the production of rice and other grain. "At the sea coast the laterite forms bluff cliffs, in the lower part of which "trap is disclosed.

"At Rutnagherry, &c., in well and other sections, the trap is found "to be overlaid by a thickness of a few feet of white clay imbedding "fruits and containing thin carbonaceous seams composed for the most "part of leaves. This is separated from the soft laterite above by a "ferruginous band about an inch thick having much the appearance of "Hæmatite. It is vesicular, the cavities being filled by quartz, &c. The "soft laterite soil above hardens on exposure, and this rapidly. It is "very thick here and along the sea coast, trap only becoming disclosed in "the deep sections, and at the base of the cliffs. In proceeding inland, "however, it is found higher up in the hills, which seems to show that "it has a westerly dip, though it is very difficult to determine the "amount, as all the sections are so covered by the detritus from the "laterite. East of Rutnagherry the latter rock extends for about fifteen "or twenty miles; beyond this the trap hills are more irregular in out-"line and increase gradually in height towards the Ghâts. The eastern "boundary of the laterite runs west of Lanji in a south-east direction, "passing east of Rájápur to Khareputtun. South of the latter place "its direction has been more correctly determined.

"About Phonda it is found nearer to the Ghâts than in other places, "it then bears to the south-west, meeting low trap hills which run out "from the Ghâts at the north of the Sawant Waree State. The "lower beds of this (the trap) pass under it about half-way between "the Ghâts and the sea. South of this the width of the formation "becomes much less, and it extends as a band ten or fifteen miles wide "along the western boundary of the State and in the narrow strip of "British territory by Vingorla.

"It occurs in great quantity in the Goa territory. In speaking of "the laterite boundary I refer to that of the laterite plateau which has a "very constant elevation, and consists, as I have mentioned, of a series of "flat-topped or slightly undulating hills separated from one another by "deep ravines which have been excavated by the rivers which drain the "country.

"There are numerous instances where this rock occurs further east, "forming patches which in many cases may be outliers of the great mass, "though oftener occurring at a lower level, being the products of the "denudation of the older laterite. These often have the appearance of "true laterite, but are more generally found as gravel, sandstone, "conglomerate, &c."

2.—Lacustrine Formations.

Few observers traverse the long valley, extending from a little west of Amingarh (Ameengurh) past Bágalkot up to Kaládgi without being struck by the idea that before the rivers which now drain the Kaládgi limestone basin had cut their beds to their present depth, a lake must have existed here. An examination of the lie of the lateritic* formation which occupies a great part of the surface of this old valley seems to support the lake theory, which will at once account for the peculiar position of the old ferruginous mud banks at which the laterite was deposited.

Ferruginous mud whence derived.

The sources whence the ferruginous mud, or a great part of it, was obtained lie close at hand in the vast beds of hæmatite and hæmatitic silicious schist of the gneiss area. A minor supply would in parts be derived from some of the conglomerate beds of the Kaládgi series which are mainly composed of debris of the great hæmatite beds. Yet another source of iron not much inferior in richness to those in the gneiss is to be found in the hæmatitic jaspery schists belonging to the Kaládgi series, and occurring in the hill ridge west of Bilgi.

Another source of the iron in the laterite exists in the Deccan trap, which in many parts contains numerous grains of magnetite.

* The name laterite is used for this ferrugino-argillaceous deposit, as it is considered to be of originally sedimentary origin, though very much altered subsequently by atmospheric influences.

The greatest development of the laterite occurs at the east end of the valley, where the iron beds of the gneiss overhung the margin of the supposed lake, or rose up as islands from its surface; but much laterite shows also in the central part, near the Anegwadi (Hungehdee) ford over the Ghatprabha. It there occurs on both sides of the river.

Most developed eastward.

This hypothetical lake serves to explain the rounded water-worn appearance of the quartzite talus along the southern base of the lower Kaládgi quartzites eastward of Bágalkot and a similar talus noticed at Sirur (eight miles to the south-east) on the south side of the supposed lake basin. The banks of ferruginous mud which subsequently assumed the laterite character were deposited upon this marginal fringe of coarse quartzite shingle.

Water-worn quartzite talus.

The extent of the old lake would appear to have been considerable, but its limits cannot be very precisely fixed owing to the presence of subaërial lateritic rocks, as well as of immense spreads of regur over great part of the Kaládgi limestone basin. In its eastern part the boundary was probably the edge of the basin formed by the upraised lower quartzites forming the synclinal valley east of the Malprabha; the continuation of the northern side of that synclinal formed the northern boundary of the central part as far as Anegwadi, where the quartzites trend to the east again, and here the lake probably had a great arm extending eastward as far as the eastern base of the Sita Dongar range of hills.

Supposed extent of lake.

The southern boundary was formed by the Sirur hills for a distance of five miles westward of Sirur itself, and then trended northward along the line of the hills forming the north side of the Shimageri synclinal valley.

It is doubtful whether the lake intruded within the area of the synclinal valley; the probability is that it did not. Westward of Kaládgi the boundary of the lake basin is very doubtfully definable, though it

most likely included the lateritic knolls for a couple of miles south of the cantonment. Still further west the boundary may have reached as far westward as Chattarband Kot (Chutturbund Kotta) eight miles west of Kaládgi. At Badnur (?) (Budnoor) and Bantur (Buntoor) a thick bed of laterite gravel with numerous fragments and chips of quartzite covers a considerable area at a level considerably above the Ghatprabha valley. This bed is also in part conglomeratic.

The laterite occurring at Kaládgi rests upon a very uneven limestone surface and is of very various thickness. South of the cantonment near the cemetery it is a very compact rock, enclosing considerable fragments of quartz. In the section shown in the jail well, from 30 to 40 feet of impure earthy laterite or "Moorum" is exposed, but it is doubtful whether much of this is not of much more recent origin than the conglomerate south and east of the town. A few miles east of Kaládgi a laterite conglomerate forms a distinct terrace abutting against the upper quartzite ridge west of Truchigeri (Troocheegaree), a similar conglomerate at about the same level forms an outlier on a sharp-cut little hill north of the village, and here rests on violet shales. Another patch of conglomerate of identical character and occupying a relatively similar position with regard to the general surface of the locality, caps a small hill about 1¼ mile north-west of Anegwadi, on the north bank of the Ghatprabha. The laterite here cannot be less than from 60 to 80 feet or more in thickness, and is exceedingly compact in texture, showing very few vermicular or vesicular cavities: fragments of quartzite that have apparently been weathered out of it lie about on the surface. This conglomerate rests against the apex of the anticlinal ellipse to the north of Anegwadi and extends to Tumurmatti (Toomoormuttee) at a corresponding level, and presents the appearance of having once been continuous with the outliers capping the Anegwadi and Truchigeri hills and also the Truchigeri terrace before mentioned. Where the laterite lies upon shaley beds, the latter have been affected to a considerable depth by the percolation of ferruginous water.

Appearance of the mud beds.

In many parts of the valley the surface generally is of a rich deep purple-brown, the rock where broken and crushed (as in the wheel tracks of some cross country roads) showing the deep red streak of the nearly pure hæmatite. The massive laterite is often of extreme toughness, but when broken shows a hæmatitic matrix with many angular grains of quartz enclosed, and presents an appearance as if the old hæmatite of the gneiss had been ground down by surf action to a perfect mud, which, on drying, consolidated around the grains of sand and hardened into its present consistency.

The surface of the laterite often shows vermicular cavities, but not so much so as the conglomeratic coast laterite. Much of the laterite occurs as gravel of various degrees of coarseness; this is sometimes pure, but more frequently contains rolled fragments of quartzite. The proportion of quartzite pebbles in some cases becomes so large as nearly to hide the laterite.

In the central and western parts of the old lake valley the deposition of the ferruginous mud was less in quantity (or subsequent denudation has been more active) than at the eastern part. Many well-marked patches of laterite remain in these parts of the valley.

The outlying laterite patches to the north-east of Yerkal in the corner enclosed between the Ghatprabha, the Krishna and the crescent-shaped hill ridge running from Yerkal to the Krishna, the Sita Dongar, appear also to have been formed in a shallow lake, probably an arm of the principal one. One section in this corner at Jerankunti (Geedran Koontee) shows a thickness of from 20 to 30 feet of vermicular conglomeratic laterite exposed in the village well.

Old lake west of Bádámi.

An independent shallow lake seems to have existed to the south-west of Bádámi and to have given rise to the lateritic conglomerate which covers a consider-

able surface in that corner of the Kalādgi basin. This lake or another of similar character occupied the valley of the Bunknuree nullah immediately to the west.

No organic remains were found in any of these supposed lacustrine formations, and this appears the greatest objection to the hypothesis of the lake basins in question, but the shape of the country and position of the shingle and iron mud deposits are all in favour of the hypothesis, for it explains the presence of these deposits in many places where they could not be referred to subaërial changes of ferruginous rocks, as, for example, where the laterite rests directly on unaltered quartzite.

3.—*Ossiferous Deposits.*

The formation which yielded the fossil mammalian and molluscan remains lies within the area occupied by the recent alluvium deposited by the Ghatprabha river along a lake-like reach* extending some 11 miles north-eastward from the town of Gokák. The most recently deposited alluvium consists of a bed of black clay formed of washed up regur of considerable thickness, and this is underlaid by the ossiferous beds consisting of dark brownish black stiff clays with partings and thin beds of gritty or sandy clay. Only one section was found in which the ossiferous beds were exposed, and this occurs in the banks of the small nullah flowing into the Ghatprabha at Chikdauli (Cheekdowleh) three miles east-north-east of Gokāk. Of the mammalia here discovered the most interesting was an extinct species of Rhinoceros which I found in 1871 and described and figured in Part I of Series X of the 'Palæontologia Indica' under the name of *Rh. Deccanensis.*

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* Described further on at page 235.

All the fossils were found in a reach of the Chikdauli nullah rises in the hills north-west of Banichimardi (Buneechmurdee) but not, as represented in Sheet 41, in the hills south of Kelvi.

The true Kelvi nullah as already shown (page) joins the great Mamdapur nullah Uparhatti.

The section seen in the banks of the nullah south of the little village is—

d. Regur or cotton-soil passing down into
c. Black clay with head of *Rhinoceros*
b. Clayey grit, two beds with clayey parting, and numerous specimens of *Uni* and *Corbicula* in the gritty bands
a. Reddish-brown black clay with bovine remains.

A number of bones and fragments of bones were found loose in the bed of the nullah, and others were obtained in 1874 by excavating in adjacent fields: these have not been examined and determined, but many are bovine and a few belong to a second and rather smaller individual of *Rhinoceros Deccanensis*. Several forms of *Unio* occur, they and the *Corbicula* all belong to species now living in the Krishna and its tributaries. The bones are found in a friable condition; they are somewhat distorted by pressure in a few cases, and much comminuted by the action of numerous shrinkage cracks in the clay. Some of the bones are much encrusted by calcareous deposits.

The nasal bones of *Rhinoceros Deccanensis* were not found, hence it is uncertain whether the animal had a horn or not, but from the absence, or very small (rudimentary) size of the incisors, the animal had probably a large horn. The individual was just adult.

The bovine animal was in the shape of its molars nearly allied to *Bibos gaurus*, which still inhabits the slopes of the Sahyádri mountains where they are thickly wooded.

4.—Fluviatile Deposits.

General characters.

The alluvia of the several rivers agree very closely in character and consist almost entirely of alluvial regur or black-soil, with some intercalated beds of sand and gravel, which latter are, not unfrequently, cemented into coarse conglomerate by the deposition of calcareous matter in the form of kunkur.

It would have been very desirable in several instances to have mapped these alluvial beds separately, but it was found quite impossible to draw any even approximately trustworthy boundary line between them and the adjacent spreads of regur. This is due to the rain-wash masking the surface of everything. This remark applies especially to the alluvium on the banks of the long still reaches of the Krishna river, which, in conjunction with the deep pools of water, completely obscures all the older underlying rocks, and which for that reason it would have been far more satisfactory to have mapped separately, if that had been practicable.

Detached alluvial basins.

In some cases on the smaller rivers the alluvium is locally confined to a well-defined flat surrounded by higher grounds, and no doubt can exist as to the extent of the alluvium. Four well-marked cases of this kind were noted on the Ghatprabha and its tributaries, and in each of these cases the alluvial flat, or basin, was found to be situated just above a narrow gorge through which the river had had to force its way.

Two of these alluvial areas, formed by small rivers, occur near Belgaum, and both occupy shallow valleys above what may be termed the eastern edge of the ghât region.

Basin of the Márkándeya river and Belgaum nullah.

The one occurs along the course of the Márkándeya (Markundee) river, a couple of miles northward of Belgaum; the other along the large nullah formed by streams rising in the Yellurgarh hill south of Belgaum and joining with those draining the Belgaum downs, and thence flowing north-east-by-east. Both terminate abruptly to the eastward by the streams entering narrow gorges in the quartzite hills, and in both cases the alluvium consists of a black-clay, a quasi-regur.

Páchápur alluvial basin.

At the junction of the Márkándeya river with the Belgaum nullah a third basin is formed, which lies south of the large village of Páchápur (Padshapoor) where the

united stream first enters a gorge in the quartzite which extends down to Gokák, a gorge which has already been described (page 87) as affording beautiful and interesting sections of the lowest division of the Kaládgi series. The lower part of this alluvial basin is completely covered by thick regur, but in the upper parts between Ankalgi (Unkulgee) and Hudli (Hoodlee) there is a great development of pale-reddish and yellowish sandy loam with much kunkur infiltration, strongly resembling typical "loess," which forms steep cliff-like banks 25 to 30 feet in height.

Gokák basin.

The fourth alluvial basin commences immediately below the town of Gokák and, as shown in the map, extends almost to Tegedi (Tegree) nearly 11 miles to the north-east. This alluvium apparently joins another interesting alluvial deposit which fills the valley of the Kelvi nullah, a tributary which joins the Ghatprabha from the south. The whole of the lower part of the basin is obscured by a thick covering of regur through which only one section penetrates. The junction of the Gokák basin with the alluvium of the Kelvi nullah is only inferential, the intervening space being completely masked by cotton-soil, but there can be little or no doubt that they do join, and may, therefore, be regarded as one basin of pluvio-lacustrine origin. The ossiferous beds under the regur, which are exposed only in the Chikdauli nullah section, are dark-coloured clays with gritty clayey sands, and contain the mammalian bones and fresh-water shells which were described above (page 232). The alluvial deposits of the Kelvi nullah valley* are gravels and coarse loam; the latter resembling that of the Belgaum nullah at Hudli described above. These

Kelvi nullah basin.

* The course of this nullah is laid down quite wrongly in the map (41). It does not trend north near the village of Banichmardi (Buneechmurdee), but continues its course north-east till it joins the Mamdapur nullah at Maldinni. The course of the Betgiri nullah to the east is similarly laid down wrong, as it falls into the Krishna west of the Ud-gatti (Oodguttee) gneiss inlier, and not, as shown on the map, close to Tegedi.

gravels rest on the various older formations forming the bottom and sides of the old valley, *viz.*, the gneiss, quartzites, Deccan trap and intertrappean beds. The gravel is in great part sub-angular and had evidently not been carried any very great distance; it contains pebbles of all the older rocks occurring in the neighbourhood. No organic remains were seen in the gravels or loam.

Washed-up regur.

It was pointed out at the beginning of this chapter that the river alluvia consist very largely of regur or cotton soil, partly washed up by the river action, and partly washed down by rain action from higher grounds. In many cases this "reguroid" alluvium is hard to distinguish, or quite undistinguishable, from the true regur, as it in great measure assumes the same character if broken up by innumerable sun-cracks, by which, in time, the laminated structure due to its sedimentary origin is completely lost.

The black regur-like alluvium occurring in the upper flat of the Márkándeya river and in the Belgaum nullah flat contains much nodular kunkur, which is collected by rather extensive excavation as a material for lime-burning.

Black silty alluvium.

In some instances the black alluvium is largely mixed with exceedingly fine sand, which, although not sufficient to affect the colour appreciably, yet suffices to deprive the alluvial deposit of the usual tenacious clayey character, so that when dry it is friable and dusty, instead of tough and lumpy. Such dry silty alluvium occurs in considerable quantity in some parts of the Krishna, as, for example, along the reach of the river below Korur, nine miles east of Sorapur.

Gravel and sand.

The black "reguroid" alluvium is the youngest and uppermost, and, as a rule, overlies the various clays, sands and gravels exposed in the lower parts of the river banks.

Large gravel beds of the age of the younger alluvia are not often met with. One of the best examples of such a gravel bed is that forming the left bank of the Tungabhadra at Chikkalbarri, six miles south of Bhima in the Raichur Doab. The gravel is typical of the Tungabhadra river, containing, besides quartz, quartzite, and gneissic pebbles, a large number of banded red and grey jasper pebbles mixed with sand. The gravel extends fully a mile inland from the river, but is then hidden by cotton soil.

Clay.

A dark reddish-brown clay occurs frequently in the banks of the Dôn river, which drains the great plain south of Bijápur. This red clay graduates upward into the black regur-like alluvium. Similar clay is not uncommonly seen in many of the other rivers.

Loam.

A considerable development of rich brown loam was observed by Mr. King in the valley of the Bhima near Ferozabad.

High level or older gravels.

In several places deposits of gravel and coarse shingle occur, the position of which cannot be satisfactorily accounted for by attributing them even to very exceptionally high floods of the existing rivers. They occur on the banks of the Krishna, Bhima and Tungabhadra rivers and some of their tributaries, at elevations from 60 to 80 feet above the ordinary flood levels.

There can be little doubt that these rivers were affected by causes not now in action, by which their waters were raised to heights vastly exceeding the very highest flood levels now attained. The causes which thus affected the rivers were probably the existence of several barriers along their courses, by which their waters were dammed back to great heights above their present level. Such barriers doubtless crossed, in former times, the valleys of the Krishna, Ghatprabha and Malprabha rivers at the several places where they have cut through the several hill

ranges mentioned in the introductory chapter. The existence of such barriers is far more probable than that the general level of this part of India has been disturbed within late geological periods.

These high-level gravels must be separated from those lying within the reach of present floods, for the former unquestionably represent a state of things very different from what now prevails, and constitute, in fact, an older alluvium, as do the high-level gravels of so many rivers in Europe and elsewhere.

High-level gravels.

Such high-lying gravels are frequent along the banks of the larger rivers, and some of the more important cases will be mentioned, beginning with the Krishna.

Of the Krishna.

1. An extensive gravel and shingle bed, consisting almost entirely of quartzite, occurs at Girgaon on the right bank of the river, sixteen miles north-by-east of Kaládgi.

2. A similar coarse quartzite shingle bed shows a little to east of Swonna (Swoon).

3. A deposit of quartzite shingle, resting partly on the trap, partly on the gneissic rocks, a little to the north-east of Buloti ferry on the Kaládgi-Sholapur road. This might possibly be in part derived from a local infra-trappean conglomerate.

4. A very considerable quantity of quartzite and quartz shingle covers the slopes of the high ground above the present flood level of the river from a little east of the Tangurgi (Tungurgee) ford at intervals as far east as Islampur (Eechanpore).

5. Coarse subangular chert shingle, some pieces almost boulders in size, occurs half a mile north-west of Korur, on the left bank of the Krishna, nine miles east by south of Sorapur.

6. A great bed of similar chert shingle, with some pebbles of quartz, quartzite, gneiss and a very few agates (the latter very common

at the lowest levels and within reach of present floods) occurs on the high bank of the river between Gondianur (Gondianoor) and Chennur, seven miles east of the last-named locality. North-east of Chennur the shingle bed must be fully 80 feet above the river bed, and 40 or 50 above the highest floods now seen. No chert shingle was seen further east than Koankal. A large spread of very similar shingle was observed (but not visited) covering the high ground between Konechupli and Kurrikihulli on the right bank of the river opposite Gondianur.

Of the Bhima.

Above the right bank of the Bhima river, beds of shingle similar to that just mentioned and containing grey chert were observed at two places; between Nellawádugi and Naikal (Nykal) to the west of the Great Indian Peninsula Railway Station at Yádghir (Yedageery), and again at Kumanur (Koomunoor) nine miles further south-east. The chert in both cases is associated with quartz, quartzite and gneissic pebbles. This high-level gravel seems to have extended across the space between the two rivers, for a considerable quantity of it occurs south of Wudigera, about half-way between the last-named gravel locality on the Bhima and Kumanur and Kônkal (Koankul) on the Krishna also named above.

The chert is very like that forming a bed at Shellugi near Talikot, and described above (p. 198). It is grey-mottled when freshly broken, and weathers with a yellowish crust. The Shellugi chert bed is of intertrappean age and agrees further with the chert of the gravel beds in showing no organic remains imbedded in it.

Of the Tungabhadra.

On the Tungabhadra river, but very little of the banks of which was examined, one very well marked gravel bed was observed at Cachapur near the southern end of the great railway bridge. This gravel consists of quartz with some quartzite and banded red jasper, and closely resembles the gravel now seen in the river bed, but it lies at an elevation of fully 80 feet above the present bed and far above the highest level now attained by floods.

Of the Malprabha.

On the banks of the Malprabha, high-lying quartzite and gneiss gravels, forming part of the older alluvium of the river in considerable quantity, were noted at Sutgatti (Sootguttee) on the right bank of the river, nine miles west of Saundatti (Sumoduttee).

Of the Ghatprabha.

Extensive traces of old high-level quartzite gravels occur on the right bank of the Ghatprabha at Wudugaddi (Woodooguddee) and Chittur; the former place three and the latter six miles westward of Kalédgi.

Four interesting cases of high-level gravels supposed not to be of fluviatile origin, but to be relics of inter-trappean and infra-trappean deposits almost entirely removed by denudation, have already been described at pp. 168, 196, and 197.

Alluvial deposits of the Bhima.

On the western arm of the zig-zag reach of the Bhima at Ferozabad, Mr. King noticed, in the steep and lofty bank below the village of Hagar Gund (Huggur Goond), the remains of a set of laminated sandstone and pebble beds. "These beds, in which no trace of fossils could be found, form low cliffs of from 10 to 15 feet high in the river bank. They are good, compact sandstones, but thin-bedded, and some of the thin beds obliquely laminated. The pebbles of the conglomerates are of Chalcedony, Onyx, &c. The sandstone is evidently a comparatively recent formation. Traces of the same beds are also seen in the side nalas, which are cut deep in the alluvium, or rich brown loamy deposit here filling up the wide valley of the river."

"A short distance north of the same village and close to this bank of the river, or inside of it, there are large accumulations of big, roughly-rounded blocks of massive, slightly vesicular dolerite, weathering brown, which do not appear to be *in situ*, but possibly are indications of boulder banks in this part of the river valley underneath

the alluvium. The connection of these accumulations of boulders with the sandstone above referred to, if any, was not traceable."

Kankar-cemented gravels at Ballur.

Cementation of the gravels into true conglomerates by deposition of carbonate of lime takes place on a large scale in many parts of the Krishna, Bhima, and other rivers and streams of all sizes. One very marked example of this is to be seen in the bed of the Krishna at Ballur (Bulloor), six miles north-west of Bilgi, in Kaládgi district. This local alluvial conglomerate is overlaid by a great thickness of clayey alluvium, chiefly consisting of re-deposited black soil. The total thickness of the alluvium here, and at the adjoining village of Hanchinal, exceeds 30 feet. None of the wells at the last-mentioned village have pierced it. The water which here filters through the alluvium is strongly brackish and considered unwholesome by the villagers themselves.

Kankar-cemented conglomerates on the Dôn.

A similar conglomerate, forming in the Dôn river below Talikot and still lower down the stream, might also easily be mistaken for a pebble bed belonging to the Bhima series, did it not contain pebbles of the Talikot limestone which forms the youngest bed of that series.

Anegwadi conglomerates.

Another noteworthy instance of conglomerate, formed by cementation of gravel and shingle in a river bed by deposition of argillo-ferruginous matter, is to be seen a little below the ford over the Ghatprabha (crossed by the new road from Goankop on the banks of the Malprabha to Sholapur) at Anegwadi (Hangehdee). This local conglomerate yielded no organic remains to determine its age, but, judged by its appearance, it is of very recent formation.

Implement-bearing gravels in the Malprabha valley.

Two beds of kankar-cemented shingle, one in the Malprabha, and the other in its tributary the Benni-halla, yielded a large number of fine, well-shaped, and mostly large-sized chipped quartzite implements, some of which were very firmly cemented into the mass and required

considerable labour for their extraction. In the former bed, which occurs at Kaira on the left bank of the Malprabha, five miles south by east of the town of Bádámi, the gravel bed is seen in the bank of the river at ordinary flood level; in the second case, the gravel occurs in the middle of the stream bed, three miles south of the junction of the Benni-halla and the Malprabha.

A great bed of gravelly kankar, with quartzite shingle and a few large chipped implements of good quality, occurs between Hire and Chik Mulingi (Heera and Chick Mootingee), about twenty miles above Kaira.

This part of the country seems to have been a centre for the implement makers, for implements of all sorts—axes, spear-heads, and scrapers in great variety—occur scattered in large numbers over the surrounding country, wherever the red lateritic sub-soil is exposed, *e. g.*, north-west of Kaira, and between Somankop and Chamankatti (Chumunkuttee) north of the basement quartzite ridge. The implements found in the river beds must have been carried a very small distance by water action, for they shew very little or no sign of attrition.

The lateritic soil just mentioned does not belong to the alluvium, but is older and most likely in part of subaërial and in part of lacustrine origin (see *ante*, page 231).

Gravels of Tolanmatti.

Gravel beds of undetermined origin, but probably lacustrine, or fluviatile, were observed at two places—one near Kaládgi, at a place called Tolanmatti, thirteen miles north-east of that station, the other along the foot of the Katharigarh (Kuttargurh) hills, near the village of Tolur (not marked in map), about eight miles north-west of Manoli.

Of Tolur.

Stone implements *in situ*.

Both of these gravel beds consist mainly of quartzite pebbles, and both yielded chipped stone implements, those in the Tolanmatti gravel occurring *in situ*, imbedded about 3 feet below the present surface of the ground.

Of the gravel bed at Tolur, which is singularly coarse, no section was seen, and the implements collected were found on the surface. All were rather water-worn.

Yelhatti gravels.

Bovine tooth fossil.

In a small patch of kankar-cemented gravel occurring on the banks of the Yelhatti nullah, nine miles west by south of Jamkhandi, an upper molar tooth of a large Bovine animal was found. The position of this patch of gravel points to its having been formed by the nullah which now cuts through it. The tooth in question is thoroughly mineralised and partly encrusted with hard kankar.

5.—*The old and recent Marine Alluvia of the Konkan.*

These are represented in the first case by a raised beach noticed by Mr. C. J. Wilkinson at Malwan, in the second place by the marine and estuarine accumulations of sand and mud, &c., forming at the mouths of the various rivers.

The raised beach is thus described by Mr. Wilkinson :—" North of Malwan the laterite comes down nearer to the sea, and round the edges of the creek, just north of the place, there are small brown sand-hills under which occur recent beds of compacted sand and broken shells dipping very slightly to the west. These are some distance above high-water mark."

As on the east coast of India, the position of the spits of sand forming the bars of the several rivers draining the Konkan depends upon the direction of the most powerful coast current, which here flows southward, so that the spits all point southward or just opposite to their direction on the east coast.

CHAPTER XI.

SUBAËRIAL FORMATIONS AND SOILS.

I.—Subaërial Formations.

Principal varieties.

Within the area treated in this report the subaërial formations which require to be noticed are those which have resulted from the reproductive action of various atmospheric agencies; such as (*a*) conglomerates formed by the cementation of loose materials by deposition of argillaceous and ferruginous cements in a simply mechanical way, or (*b*) similar deposits cemented together by the chemical precipitation of calcareous matters, and tufas; or other formations also resulting from the same class of agencies, such as purely pluvial aggregations (*c*) and blown sands (*d*). Yet another class (*e*) is that of formations greatly changed by the percolation of atmospheric moisture in large quantities as the 'iron clay' and other lateritoid rocks; in these the change is both chemical and mechanical.

The first and last of these five classes of subaërial rocks are most largely represented in the South Mahratta country. Several very remarkable instances of cementation of talus débris will be described in the following pages. Tufas, though not uncommon, are, as a rule, of small importance, and no blown sands of importance were met with anywhere, while the rocks which come under class (*e*) have already been fully dealt with in Chapter VIII.

Conglomerates formed by ferrugino-argillaceous cement.

a.—Subaërial Conglomerates and Breccias.—Cases of the cementing of talus and of débris of quartzites of the Lower Kaládgi series by the deposition subaërially of ferrugino-argillaceous matter were noticed at Sonapur a little south-east of Katharigarh, and three miles further west on

the plateau east of Murgod; at these localities numerous large pebbles of quartzite weathered out of a sandstone conglomerate have been re-cemented in very nearly their original position. The new rock looks very like a pavement of artificial construction. A very similar but even more striking effect is produced by the cementing of rounded quartzite talus in the valley south-south-west of Tumurgudi (Toomoorgoodee) and about eleven miles north-east of Belgaum. This pavement extends for several hundreds of yards along the path and for a considerable distance right and left in the jungle.

Breccia.

A case of cementation of angular fragments of gritty quartzite into a breccia by the introduction of a red arenaceous cement was observed in the saddle between the north-east side of One-Tree Hill at Belgaum and the south-east corner of the quartzite plateau to the north-east. This breccia might from its position be easily mistaken for part of the Lower Kaládgi quartzites, the coarse pebbly basement beds of which are exposed close by and seem to rest on highly upturned micaceous schistose beds in a section a little to the north-east of Kunburgi.

Instances of the formation of small patches of subaërial conglomerates and breccias by lateritoid decomposition of ferruginous rocks *in situ* of all ages are extremely common and may be found almost everywhere. They are so common, in fact, that there is no need to name any examples.

Conglomerates and breccias with calcareous cement.

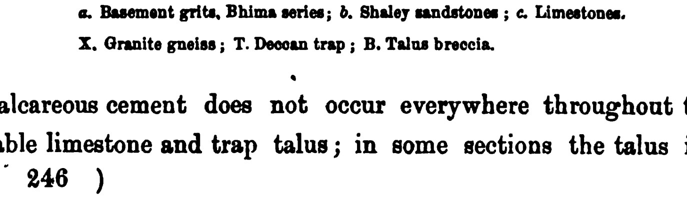
In the Bhima basin.

Several very interesting and important examples of tufa-cemented breccias and conglomerates were met with at the foot of the low hills north of the Krishna in the Sorapur Taluq, where these hills are capped with the limestones which form the upper member of the Bhima series in that region. The most important examples occur in the large and nearly circular valley lying

north-west of Sorapur and just within the Nizam's territory (Sheet 57, S.W. quarter) near the western side of the valley. These accumulations have been largely formed by the unequal degree of weathering of the shales and overlying limestones, by which the surface of the valley for a mile or two from the present edges of the limestone plateaux is covered with an immense talus of limestone fragments of all sizes mixed with a smaller number of trap fragments.

These are in many places cemented together into breccias or conglomerates of enormous coarseness by the deposition of carbonate of lime in large quantity. The sandy material of the underlying shale beds has been for the most part swept away previous to the deposition of the calcareous cement. Of the included rocks many are angular (I think the greater number), and the remainder rounded, more probably by atmospheric action than by any aqueous attrition.

The trap blocks are mostly rounded owing to the great extent to which concentric weathering has gone on even in the most undisturbed trap-flows. I could not see any signs of subaqueous deposition in these conglomerate beds, which I believe to be of purely subaërial origin. The accompanying sketch illustrates the formation of these conglomerates and breccias by simple subaërial action.



Formation of a talus breccia.

a. Basement grits, Bhima series; b. Shaley sandstones; c. Limestones.

X. Granite gneiss; T. Deccan trap; B. Talus breccia.

The calcareous cement does not occur everywhere throughout this remarkable limestone and trap talus; in some sections the talus is seen

to be loosely aggregated, the interstices between the blocks being filled with various soils washed in by rain-action.

Landslips.

In the two cases of landslips described at p. 152 the limestone fell, or subsided, in enormous masses, which, though occupying the same position on the gneiss, cannot be considered as having been incorporated in the conglomerate formed by the deposition of calcareous matter among the general mass of the talus. In this valley the talus-conglomerate extends from Yeddihalli to near Hundurahal.

The same phenomenon is well seen some miles to the south-west at the foot of similar limestone plateaux a little to the east of Kaldevanhal (Kuldewunhul) and Marunbhavi, where the amount of calcareous cement is even greater and more conspicuous. Many sections in these singular deposits, which are locally 10 to 12 feet or more thick, were most carefully searched by me, but without discovering any trace of organic remains enclosed in them. A little to the west of Yeddihalli, and also to the east of Arukeri, several well-shaped chipped stone implements were found lying on the surface of the conglomerate from which they had apparently been washed out.

Chipped implements of limestone.

The fact of these implements being made of limestone is interesting, this being the first case in Southern India in which chipped implements have been discovered which were not manufactured out of quartzite pebbles. No real quartzite occurs immediately in that neighbourhood, and the hard, compact, and rather silicious limestone with a strongly conchoidal fracture, was a stone not altogether ill fitted to replace the harder quartzite, in the absence of a better substitute.

Another example of such breccia conglomerates was observed by Mr. King, Deputy Superintendent, Geological Survey of India, on the slope of Lálápur hill in the south-eastern part of the Bhima basin (see p. 153).

A good example of a re-formed conglomerate, [in which the pebbles and gritty sand formed by weathering of gritty pebble beds, have been recemented by calcareous tufa, occurs on the north side of the Jamkhandi hills, where it rests upon and masks the boundary of the Deccan trap for a considerable distance. The original pebble beds belong to the Lower Kalâdgi quartzite series.

b.—*Tufaceous Deposits.*

Calcareous tufa deposits.

Of calcareous tufa formations three classes occur,—the first, in which the tufa forms solid masses of rock; the second, in which the calcareous matter occurs in detached gravel-like nodules or true "kankar;" the third is the root-like cylindrical form occurring in matted aggregations in the banks of streams. The former was rarely noticed in any quantity, and in only one case is deserving of notice; the two latter are extremely common and are invariable accompaniments of true regur.

Massive tufa.

The only noteworthy example of the first class occurs a little south of Banshankri Pagoda, a celebrated shrine 2½ miles south-east of Bádámi. An area of several acres in extent is there covered with large irregular masses of a perfectly concretionary tufaceous limestone, unlike anything belonging to the older limestones of the district. No section was seen shewing the relation of this tufa to the underlying rock, but it is very likely that it covers a thin bed of calcareous shale, such as occurs further west, or from which the calcareous matter was doubtless brought down by the streams. I am inclined to think this tufa is in part certainly due to human agency in damming up the large nullah which flows past Banshankri from the west. A large swamp has been formed to the west in an otherwise perfectly arid sandy valley.

Gravelly tufa or kankar.

Of the second class of tufaceous deposits, only two accumulations of kankar gravel, both lying on the Deccan trap, deserve special notice.

The first of these occurs on high ground six miles north-east of Muddebihal, and covers a great extent of ground. The kankar is of pale red color and forms banks of unconsolidated gravel.

The second case, which occurs on high ground between three and four miles north of Mudhol, is of precisely the same character in every respect. The spread covers many hundred acres, and is in places fully twelve feet or more in thickness.

Tufa of the third class is also very common, and no particularly striking or instructive cases require to be adduced.

c.—*Pluvial Formations.*

Pluvial aggregations.

Pluvial aggregations are by no means rare in the mountain region, especially on the flanks of trap mountains, and at the sides of some of the larger valleys. Much of the quasi-lateritic soil and rock met with in such positions is of purely pluvial origin in the first case, but as a rule this class of deposits is so much mixed up with the immediately local results of weathering action that no line of separation can be traced. Considerable areas were met with, especially in the neighbourhood of Belgaum, which were covered by such formations in thickness sufficient to mask the true sub-rocks and to necessitate the mapping of the subaërial deposits.

Sand talus.

It was mentioned before (page 244) that no blown sands of any importance were observed, but large tracts of the quartzite region are covered with almost pure sand; for example, the country north and west of Bádámi, at which place itself a considerable talus of pure sand surrounds the red quartzite-sandstone cliffs. Similar sand talus was also noted at Persapur on the north side of the Gudur-Hanamsagur quartzite plateau, and to a smaller extent along the northern slope of the hills north-east of Mamdápur in Gokák Taluq.

Coarse débris talus.

Talus accumulations of rock débris are to be met with everywhere and are often very extensive, especially at the foot of quartzite slopes and scarps, where they render the ground very rough and impassable. Occasionally they are so thick as to obscure geological boundary lines to a very great extent, and in two cases it was found needful to map the talus-covered areas distinctively. These cases occurred, one to the north-east of the Nelseri traveller's bungalow on the Belgaum-Kaládgi road, the other at the base of the great quartzite headland* forming the easternmost extremity of the Kaládgi quartzites lying south of the Malprabha river in the state of Rámdurg. In both cases the accumulation is considerable in thickness, and forms a conspicuous feature of the locality.

II.—Soils.

Two classes, black and red.

Two great classes of soils are found covering the South Mahratta country and south-western Deccan, the red and the black; and besides them, a few exceptional forms not to be referred to either in point of color. The red soils are primary soils resulting directly from the decomposition of ferruginous rocks of all kinds; the black soils, on the contrary, are secondary soils,—that is, they are the results of primary decomposition altered by accession of organic matter from the surface. Both classes of soils are met with on all the different rocks. The old idea, that regur or cotton soil is the result of the weathering of trap rocks only, meets no support in the country here treated of, for black-soil occurs quite as largely and typically on the gneissic and other azoic rocks here occurring as it does on the trap in the southern parts of the great trap area.

* Locally known as the Suriband (Sooreebund) Hill from the village of that name. It was at this village that Mr. Manson, the Assistant Political Agent for the South Mahratta country, was attacked and murdered by the rebel Rajah of Nargund in 1858.

Regur.

The great regur-spreads on the watershed between the Krishna and Tungabhadra in the Raichur Doab and the great "black plain" in the north-eastern part of Dharwar district, all resting on gneissic rocks of all kinds, are far more extensive and homogeneous than those on the trap north of the Krishna. It is clear, therefore, that regur may, under suitable circumstances, be formed by organic alteration of the primary products of weathering of almost any rock, if they are sufficiently argillaceous in quality.

Cases in which the regur-spreads are conterminous with the trap rocks may possibly occur, for they do so largely in Central India near Nágpur and Chánda,* but a very large number of cases could be adduced where one and the same regur-spread stretches, without break or change, across two or even three groups of rocks of totally different geological age, the trap being one in every case, and yet in these instances the regur is not alluvial, *i. e.*, has not been subjected to more movement than results from pluvial action.

Very numerous cases were observed of the trap weathering into red, or reddish, or yellowish-brown soils. As the country rises towards the

* See Memoirs, G. S. of I., Vol. VI, p. 235, where the subject of the formation and occurrence of regur is very tersely and clearly handled by Mr. W. T. Blanford.

The idea that the regurs of Southern India are generally poorer than those of the Deccan trap area and Central India, appears to me to be ill founded, if, in the latter case, I may judge by the appearance of the crops and trees seen from the railway between Jabalpur and Nasik, a route that I have traversed several times during and after the rains. The jowari crops, for instance, grown in the great black plain of Dhárwar district, and in the great regur-covered valley of the Khundair in Karnul and Kadapah districts, especially the latter, are far superior to anything seen in the Deccan, or, as far as my observation extended, between Nasik and Jabalpur. The paucity of trees in the Ceded Districts and other Canarese districts is in great measure due to prejudice on the part of the natives, who believe that if they allowed trees to grow plentifully, they would lose all their crops by the huge flocks of mynas and other birds which would then increase prodigiously in number. It should also be borne in mind that several of the largest regur-covered districts in the south are situated in districts where the rain-fall is far less than one-half of that received in Central India. The fertility of the regur when irrigated is immensely increased.

Ghâts, the red and brown soils, formed by direct decomposition of the basalts and amygdaloids, increase greatly in quantity, and the black regur soils are seen as a rule only in hollows, or valley bottoms.

Red soil prevalent in the Ghât region.

In the Ghât region itself this phenomenon is yet more strikingly, developed, and black soil becomes quite a rarity. Even the alluvia are reddish yellow or mottled clays, except after long-continued cultivation. Finally, on the high ranges, black soils are seen to form only in small swampy patches, covered with coarse tussocky grass. These black swamp soils are much more akin to a rich humus with peaty characters than to ordinary regur. Not a trace of real peat was, however, seen anywhere, though very carefully looked for; and the absence of it may, with good reason, be ascribed to the insufficient elevation of the mountains, for the climate is, in point of wetness, far better suited for the production of peat than many of the drier but more elevated mountains further south in the Peninsula,—*e. g.*, the Shervaroy hills, where peat forms largely at an elevation above 4,000 feet. In the Wynád, peat forms at even much lower levels, but there the gneissic rocks may yield more suitable materials for the inorganic part of peat swamps.

Black swamp soil.

Absence of peat.

Greenish grey trap soil.

Amongst the exceptional forms of soil named at the beginning of this chapter as not conveniently referable to either of the great classes of the red and black soils, are the pure sands derived from decomposition of some of the quartzite and grit beds of the Kaládgi and Bhima series, and also the grey, or drab, or very pale olive green soils derived from the final decomposition of the earthy weathering basalt, or "wacke" of German geologists. This pale-colored half-sandy soil occurs largely in the trappean country, especially among the lower flows in the more eastern part of the area. This form of weathering seems almost as characteristic of basaltic rocks in the dry portion of the Deccan as the lateritoid weathering is in the mountain region.

Saline soils.

The last of the exceptional kinds of soil are the soda and potash soils, which are, however, but very little developed within our area. Large quantities of the alkaline salts occur in some of the other soils, especially in the regur, as is proved by the highly saline character of the waters of some of the streams draining large spreads of it.

The most important of these is the Dôn river, the waters of which are so saline as to be undrinkable except in flood-time. The Dôn is called a "salt-water river" on many maps—a name which conveys an exaggerated idea of the salinity of its waters, which may best be described as very brackish during the hot weather. The source of the salt must be deep-seated, for the regur, which occupies the main part of the valley, is famous for its fertility. It bears immense crops of jowari (*Sorghum vulgare*), and was formerly known as the granary of Bijapore, and its fertility has become proverbial in a Canarese saying, which asks—"If the crop of the Dôn valley fails, who shall eat? if it ripen, who shall eat (it)?" The large nala which flows into the Dôn from the north-east at Talikot is even more brackish than the river itself, and parts of its bed when dry are crusted over with a thick layer of impure salt.

Other very highly saline streams are the Hiralla Naddi, which drains the great regur-spread north-east of Ling Sugur, and the large nala rising in the Agani-Kembhavi valley west of Sorapur. A large quantity of salt is raised at Baichubál (Bychubal), on the banks of the last-named nala, from brine springs, by means of wells sunk below the regur surface to the depth of 120′ according to Colonel Meadows Taylor, who mentions also that crystals of gypsum and sulphate of soda (Glauber salts) are brought up from these wells.* The water in many villages standing on the regur spreads is of very bad quality,—almost undrinkable indeed,—*e. g.*, at Agani on the southern

* I was accidentally prevented from visiting the Baichubál brine-pits.

branch of the Baichubál nala. Guineaworm was exceedingly common at this village, so much so that my servants (Madrassees) got frightened and requested to be allowed to move camp to some other village. Whether this was merely accidental, or whether the quality of the water favored the development of the parasitical worm, is a question that may interest naturalists devoted to the study of the entozoa.

With regard to the soils occurring in the central and eastern parts of the Bhima basin, Mr. King writes as follows in his notes:—

Brown-black trap soil.

"The trap country is generally covered, except in proximity with the more clayey, vesicular, and zeolitic traps, by the dark brown, nearly black soil, so closely resembling cotton soil in appearance. This deposit is, unlike the cotton soil of Southern India, evidently due in great measure to the decomposition of the rocks either beneath it or in its immediate neighbourhood. It is ferruginous and is in many instances seen to pass down gradually into a brown or red clayey and somewhat ferruginous stony covering or form of the trap itself. It is also full of small fragments of trap. Such a soil may be well seen over the country south of Gulbarga towards Parwattabad, and beyond this where the trap borders either bank of the Ferozabad zigzag reaches of the Bhima.

Amygdaloid trap soil.

"A brownish black and grey soil such as extends southward from Gulbarga past Rajahpur is occasionally seen. This is glittering at times with large and small particles of a silvery white zeolite (? Scolecite). The same kind of soil may be seen all over the country to the north-east of Gulbarga wherever denudation has cut down through the higher plateaux of black basaltic trap of that region, to the intermediate beds of grey or brown vesicular and amygdaloidal traps, which are at about the same level as the low grounds south of Gulbarga town, as in the valleys of the Benathora and Mulamari rivers.

True regur.

"True cotton soil was only seen here and there. The low plateau hills five miles south-east of Gulburga, for instance, are capped by cotton soil, the country below being of the dark-brown soil, with fine trap débris.

"At the same time it should be mentioned that in very many cases the dark-brown soil above referred to appears to shade gradually into what may be considered as cotton soil; that is, that without very close and possibly analytic examination, a boundary could not be drawn between the two."

CHAPTER XII.

ECONOMIC GEOLOGY.

The mineral wealth of the South Mahratta country and adjacent districts is, practically speaking, of very small importance, for the different geological formations they contain possess nothing available in any quantity except building-stones and iron ore. For the former of these there is nothing but a local demand, and for the latter even the local demand is diminishiug rapidly owing to the great increase in the cost of charcoal for fuel. A brief enumeration of the most important cases, ancient and modern, in which stone has been used architecturally, with notice of new localities whence remarkable and valuable kinds may be obtained, will now be given, taking the several formations in their geological sequence.

Building-stones of gneissic age.

To begin with the gneissic rocks: but few varieties of these are utilised, the granitoid variety excepted. This has been employed in constructing the most important of the old fortresses in our region, *e. g.*, Raichur Yadgir, Shápur, the two Beydar strongholds of Sorapur and Wakinkera (Wagungerri of Sheet 57), and lastly Mudgal. In many of these the walls are in part cyclopean in structure; a splendid example may be seen at the eastern gate of Raichur town, where some of the grey granite blocks fitted together without cement, truly deserve to be described as megaliths. Granite gneiss has been largely employed in different structures belonging to the Madras Railway, and notably in some of the piers of the great bridge crossing the Tungabhadra at Kasapur (Kachapore).

A very beautiful variety of rather fine-grained pale grey granite gneiss forms the low hill on the east side of which stands the large village of Gobur fourteen miles from Raichur. For durability this variety

stands pre-eminent. Several old unfinished Jain temples south of the village shew hardly any traces of weather action despite their antiquity.

Porphyritic gneiss.

Many beautiful varieties of porphyritic granite gneiss occur in different parts of the gneissic area, some of which have already been enumerated, as the red varieties at Jaldrug and Bandola on the banks of the Krishna and the red and green syenitic variety occurring at Gajendragarh (Gudjunturgurh of Sheet 58). A similar but less handsome red and green variety occurs at Bilgi, north of Kaládgi, underlying the basement beds of the Kaládgi series. An exceedingly handsome but less markedly porphyritoid variety forms the high hill west of Mosulukal, in the Raichur Doab. It is a red syenitic rock with wavy laminations surrounding small dark nuclei producing an effect like "bird's eyes" in wood. It is susceptible of a high polish and could be quarried in large and long masses, the jointing being favorable.

Pistacite gneiss.

Banded granite gneiss containing much epidote (pistacite) in lieu of mica or hornblende occurs largely in the bed of the Bhima between Lingary and Kumunur (Koomunoor), also on the south bank of the Krishna, ten miles south of the last-named place, near Gagalu and Gugalu (Gaguloo and Googuloo of Sheet 57). A great supply of extremely handsome stone could be obtained at either of these localities.

Granite gneiss near Belgaum.

The band of granite gneiss south of Belgaum, between Ganibail (Gunnehbyle) and Khanapur, might be made available for important public buildings in Belgaum, and the stone there obtained would, from its excellence, be worth the greater expense incurred by carrying it for much greater distances than the basaltic rock now used.

Schistose rocks.

Of the schistose varieties of the gneissic series much use is made for rough purposes. The whole of the town of Hunugund (Hoonugoonda), for example, is built of the poor hæmatite schist forming the Hunugund hill.

Iron ores.

The very rich hæmatite schist of the Jiaddigudda hills near Tawurugiri in the Nizam's territory used formerly to be smelted at that town, and produced iron and steel of excellent quality, much in request by the Hyderabad armourers. Of late years, however, the smelting industry has died out there, owing to failure of fuel.

Iron smelting.

A small quantity of good ore, obtained from the great hæmatite beds near Amingurh, is worked at Sindunhal near Aiholi in the Malprabha valley in a furnace differing somewhat in form from those ordinarily used in the Telugu and Tamil districts. Such a furnace will be found figured on p. 264. The outturn here was stated to be 10 viss per diem.

Chloritic and talcose schists are only used for rough walls, flagging, &c., but there are beds of chloritic rock, in the eastern part of the gneissic area, quite equal in quality to that of which the famous temples of Gadag (Gudduck) in Dharwar district are built, and equally susceptible of being most elaborately and delicately carved.

Dolomite marble.

No use appears now to be made of the magnesian limestones or dolomites occurring in the gneissic series on the slopes of the Ghâts east of Goa. Whether any of the marbles used in the great churches and monasteries at that place were derived from this dolomite series I have not been able to ascertain. The beds exposed in the Bhimgarh mountain would be unfit for polishing, owing to the numerous thin folia of granular quartz which everywhere permeate the rock, but doubtless beds free from these folia might

be found, and they would be very valuable for building or decorative purposes.

Manganese.

Besides iron, the only metallic ore which occurs in any quantity beyond mere traces is an earthy powdery form of binoxide of manganese, answering nearly to "Wad," found as a product of weathering among the dolomite at Bhimgarh. To what extent it occurs was not determined, as I discovered it only just as I was leaving the place, and had no opportunity of revisiting it. If met with in good quantity, it might be useful in the manufacture of purple glass or as a bleaching material.

Gold.

Gold is found in very small quantities in some of the streams flowing into the upper part of the Malprabha, from both sides, through a region occupied by chloritic schists with rather poor hæmatite schist intervening. The exact source of the gold supply remains to be determined. The yield is so exceedingly small that these streams are now but very rarely visited by the jalgars or gold-washers. Very few quartz veins occur in this region, and none were noticed with a north to south course. A small stream, a little westward of the village of Belowaddi, appears to be the most auriferous, but I failed in getting an appreciable quantity of gold in a number of carefully selected samples of sand and gravels collected in promising places in the bed.

Oldest Trappean Rocks.

Of the older trappean rocks, *i. e.*, those older than the Kaládgi series, though so largely developed in dykes throughout the gneissic region, but very little use has been made except in one case, namely, in constructing about three-fourths of the piers of the great bridge by which the Madras Railway crosses the Tungabhadra at Kasapur. The basaltic diorite here used was quarried from the great Bichal Gutt dyke, the largest and most striking member of the Doab series of dykes (see page 57). The jointing of the rock in the dyke was found very

convenient for turning out large blocks admirably fitted for building purposes, being hard and tough in the extreme. The bridge in question is a very fine work, and reflects high credit on the Railway Company, and especially on the engineers more immediately concerned in the construction, Mr. Henry Gale, C.E., and Mr. William Robinson, C.E.

The Kaládgi Series.

A very large and varied supply of excellent stones for building and other purposes is obtained from the different members of this great rock series. The localities yielding good sandstones, both thick and thin-bedded, are very numerous, and only the most important will be named, beginning at the most easterly extremity of the Kaládgi basin.

Both at Hanam Sagar and Gudur sandstones have been largely quarried, and again at Aiholi, or Aiwali (Iwullee of Sheet 58). At the latter place are numerous old Jain temples built of fine cream-colored or pale reddish yellow brown sandstone, with elaborate mouldings and carvings of great beauty.

Jain temples at Aiholi.

The suitability of the stone greatly aided the skill of the sculptors, some of whose works are really of great merit, especially the caryatides and other figures in the temple with an apsidal back standing in the village.

Other Jain temples built of stones from the Aiholi quarries occur at considerable distances from them, *e. g.*, two fine temples which stood on the end of the Hunugund ridge some years back overlooking the town, but of which the finer, a gem of carved stone work, was pulled down by some barbarian in the Public Works Department. Another group of temples stands at Patadtkal,* some miles further up the valley of the Malprabha than Aiholi. Three other groups of Jain temples at Magandi,

* The name of this village has been accidentally omitted from Sheet No. 41 of the Indian Atlas.

Bádámi, and Sirur, are also built of fine sandstones and quartzite sandstones, the former variety having in all probability been brought from the Aiholi quarries, for they are finer in texture than anything near the temples in question. A rath, or temple car, at Aiholi is mounted on four equal wheels of fine-grained red sandstone, 5 feet in diameter; another at the Banshankri temple, near Bádámi, has equirotal wheels fully 7 feet in diameter, each cut out of one homogeneous slab of precisely the same red sandstone. I could not find out where these fine wheels had been quarried, nor did I come across such a sandstone in my wanderings, but it doubtless exists somewhere near the Aiholi Jain settlements. Different in kind are the remarkable cave temples at Bádámi already referred to at p. 107, which are cut into instead of out of rock of the same age. One of these, the most easterly, seems to be purely Buddhist. The other three are of Jain origin, and contain figures of many deities and personages besides Buddhas, which alone ornament the sides of the easternmost cave temple.

Quartzite.

Perfect quartzite, on account of its hardness, is rarely employed except in the rough. One very notable exception to this occurs at Bilgi, twelve miles north-east of Kaládgi, where the highest hill south of the village is surmounted by a very fine stambha, or sacred lamp-post, cut out of typical waxy-lustred quartzite of very pale pinkish drab color, said by the villagers to have been quarried close to the spot where it stands. Considering the refractory nature of the stone and the extreme rarity of finding a quartzite bed which is not broken up by jointing into small masses, this beautiful monolith is a most remarkable specimen of stone-cutting skill. Including the base, which is built into a square basement pile, the whole stambha must be nearly, if not fully, 35 feet high, but it is only 1 foot 6 inches square at the surface of the basement structure. The pillar has been cut into an octagon for the greater part of its length, but at intervals it was left square in order to afford steps by which to climb up to the lamp fixed

The Bilgi Stambha.

on the top. Nothing of the history of this fine monolith seemed to be known to the villagers, so it is probably of some antiquity; but if this be the case, it is very remarkable, seeing how very exposed the position in which it stands, that it should not have been struck and destroyed by lightning.

Modern buildings.

Of modern buildings constructed of sandstones belonging to the Kalâdgi series, only two need be named,—the cantonment church at Belgaum, and the bridge over the Ghatprabha at Sutgatti (Sootguttee) on the Belgaum-Poona road. The stone used for the church was unfortunately not well chosen, being too gritty and porous to answer well in so wet a climate as that of Belgaum during the south-west monsoon.

Small stone articles, such as hand-mills, curry-stones and small troughs, are largely manufactured by the Waddras (Wudders), a roving tribe of stone-cutters at various places,—*e. g.*, to the west of Bilgi, to the south of Kotchi, in Ram Durg State, and at Ramapur, eight miles east of Bâdâmi.

Some of the very thick-bedded sandstones to be seen at Gudur, at Parvati, near Guledgudd, and elsewhere, appear to be thoroughly suitable for large millstones, such as are employed in first-class mills in Europe. An experiment with these beautiful sandstones might be well worth trying.

Fine flagstones may be procured at Halikeri (Allehgeeree, fourteen miles south of Kalâdgi), where they are largely raised by the natives.

Among the higher members of the series are the dark-greyish, black, gritty clay rock occurring at Sillikeri (Shoolehgeeree of Sheet 41), south of Kalâdgi, which was being quarried to some extent for small flagstones to be used in some palace building at Kolhapur. Close by are the quarries whence a considerable quantity of hard thin shale was quarried in former years for the purpose of being used as roofing slates on public buildings at Belgaum. They do not seem to have

answered well, as they are no longer in use for that purpose. In the same way, there is now no longer any demand for the hones that used formerly to be quarried in a bed of very hard clay schist at Khaterki, north of Belgaum.

The limestones of the Lower Kaládgi series* are used to some extent as building-stone, and a series of experiments tried in the jail by Dr. R. Thorpe, when Zillah Surgeon of Kaládgi, shewed that many varieties were capable of taking a high polish, and thus forming marbles of great beauty and value for decorative purposes. Some beds are locally of sufficiently fine and close texture to be available for lithographic purposes; in this respect, however, they are inferior to other limestones of the Bhima series to be mentioned a little further on.

A black clay slate, with delicate green bands, occurring at Kaládgi would also yield a very beautiful stone for decorative purposes.

Shales used as "wash" for houses.

In some places the purple shales are dug out and ground down to be used as a wash for houses and walls; white shales are also sometimes similarly used. The former are worked near Kaládgi, the latter at Reddi Timapur, in Bádámi Taluq.

Iron ore.

Iron ore is worked to a very limited extent in the Kaládgi series: 1*stly*, at Bisnal, nine miles west of Bilgi, where it occurs as silicious red hæmatite schist (see p. 84).; this ore is smelted at Siddapur and Jainmatti (Iehnmutte), two villages in the neighbourhood; 2*ndly*, brown hæmatite, forming the matrix in a hornstone breccia occurring at Bassargi (Bussurgee, p. 112), is smelted at Teggihal, both villages on the banks of the Malprabha between Manoli and Torgal.

The annexed sketch shews the form of smelting furnace used at Siddapur, and also at Sidanhal (Seedunhal) near Aiholi, on the right

* See page 116 for an account of the varieties met with and localities where they are to be found.

bank of the Malprabha.* The furnace is constructed of red clay, and at the latter place, where the clay is very bad in quality, the chimney

Native smelting furnace at Siddapur.

is hooped with iron in several places. The furnace is worked with double-skin bellows of the ordinary construction, with yoked iron nozzles passing into a clay tuyère which enters the triangular aperture at the side shewn in the figure at T. The daily out-turn at Siddapur was 8 viss = 24lbs., valued at 1½ rupee.

The ore used is a very poor, dusty material, a product of weathering of the tolerably rich hæmatite schist. The smelters had no blooms ready as they were at the time of my visit just resuming work after a long holiday; but some of their tools, made of the iron they produce, shewed it to be of very poor quality, flakey and coarse in grain.

The Bhima Series.

Little else but building-stone is yielded by the rocks of this series, and this is chiefly obtained from the limestones; but these are very largely used owing to the great ease and cheapness with which they can be obtained and to their extreme suitability for building purposes. The most

* The ore smelted at Sidanhal is brought from the great hæmatite beds west of Amingarh.

important examples of their use are the ancient fortified city of Ferozabad* on the Bhima (which was entirely built of the limestone), the town of Talikot on the Dôn River, and various new buildings belonging to the Great India Peninsular Railway. The limestone is so much esteemed that it was and is still carried to considerable distances beyond the boundaries of the Bhima basin. As already mentioned (*ante*, p. 154) the cream-colored variety is the most esteemed locally, and justly so, for it gives a very pleasing appearance to the villages which are built of it.

Experiments on the value of the stone for lithographic purposes have been tried both in Bombay and Madras, but they cannot have been successful, for no demand has arisen for it for such purposes.

A few small slabs of the grey and purple varieties are to be seen used as panels in an oriel window in the very beautiful little building known as the Mehtri Mahál at Bijápur.

Chipped implements.

One very interesting application of the Bhima limestone in very ancient times was to the manufacture of chipped stone implements, several excellent examples of which were found by me near Yeddihalli (see p. 162).

Iron pyrites.

Iron pyrites occurs in tolerable quantity in some of the limestone beds, and is (or was) used for the manufacture of sulphur at Mudanur (Moodanoor) in Surapur Taluq according to Colonel Meadows Taylor.†

Of the quartzites and sandstones some use is made in building, especially near Muddebihal, and hand millstones of good quality are quarried in some quantity at Inuchgal, some seven miles to the north-east by east out of a bed of pale purple grit containing occasional green chloritic grains.

Dolmens.

Rude flagstones of large size from a semi-schistose semi-conglomeratic gritty sandstone immediately underlying the Talikot limestone between Tirth (Teertu

* Founded about the end of the fourteenth century by Feroze Shah, 7th King of the Bahmaní dynasty.

† I was not aware of the existence of this industry when I visited Mudanur in 1870, so made no enquiries as to the extent to which it is carried on.

of Sheet 58) and Bazuna Kolur have been used for the construction of a group of very fine and well-preserved dolmens a little to the south-west of the last-named village. One fine top slab measured 11′ by 7′ by 1′ 2.″ All the dolmens had been violated by openings effected between the upright stones.

The Deccan Trap.

The various trap-flows furnish little or nothing but building or road materials; the latter is excellent, but the former is generally of inferior quality, because of the great difficulty of shaping the rough stone. Though but little used now in the South Mahratta country, the value of the basaltic rocks for ordinary and decorative building purposes may be well studied in the immensely extensive and frequently grand ruins of Bijápur.

At Bijápur well-selected stones have worn well, and many still retain much of their original sharpness. Beautiful carvings, chiefly arabesques and traceries, may be seen in the Ibrahim Roza, the Mehtri Mahál, and Jamma Masjid, not to mention many other less important examples in the many mausolea scattered about in every direction. The whole of the immense walls surrounding the city, together with Turweh, are built of well-tooled basaltic rock.

Beautifully carved tracery is also to be seen in the great Durga and cloister surrounding the grave of Ibrahim Adil Shah, King of Bijápur, at Gogi in the Surapur Taluq.

Red bole has been successfully used as a paint, but, I believe, only in an experimental way. It should be cheap as it could be obtained easily in many places.

The Deccan Iron-clay (Laterite).

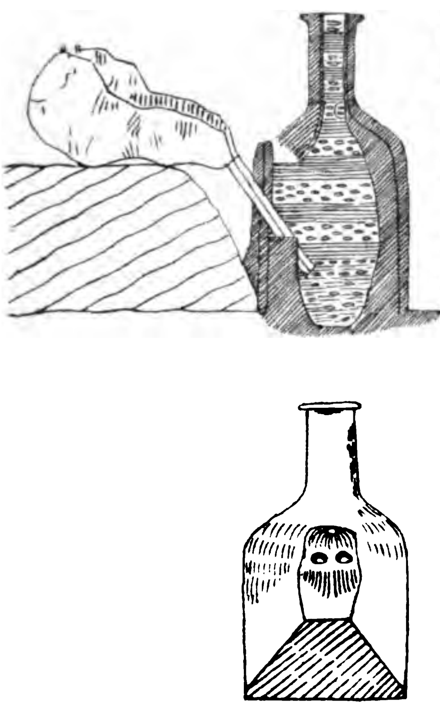
The iron-clay is but little used now, except as road metalling or for very unimportant structures; but in olden times it was largely used in great works,—for example, the great fort of Belgaum and the hill forts of Kalánandigarh, Sámángarh, Wallabgarh, Paizargarh (or Pawitrigarh), and various pagodas, such as those at Chandgarh, Kun Kumbeh, and Kodali (Kohada of Sheet 41).

Like the true sedimentary coast laterite, the Deccan iron-clay is soft and sectile below the surface and hardens subsequently on exposure; they agree also in being very variable in their resistance to crushing power, so that they are not trustworthy for structures of large size.

Konkan Laterite (Iron-clay).

The Konkan laterite is worked to a small extent, where richly hæmatitic, as an iron ore, and is smelted in small clay-built furnaces, of one of which the annexed figures show the elevation and section from drawings by Mr. Wilkinson.

These small furnaces, called "battis," are used in many parts of the small state of Sáwant Wári. When charged, the elliptical or rectangular-shaped opening in front is closed by a mass of soft clay in which two holes are left for the passage of the two tuyères which are directed downwards. The third hole at the top is left open, but is closed with a lump of clay when reduction is taking place and the contents are sinking down, being opened from time to time for the passage of an iron rod to push down the contents of the furnace. The ore is first crushed into a coarse powder and then placed in alternate layers with the charcoal; the lowest course consisting of charcoal.



Native smelting furnace used in Sáwant Wári.

Alluvial Deposits.

Nodular kankar or calcareous tufa is used largely for lime

burning all over the area under report. Near Belgaum such kankar is collected, for the Public Works Department, by excavating trenches in the alluvium, something like the coprolite diggings in the green sand in England.

Salt and saltpetre are collected by evaporation from the waters of numerous streams in the manner common throughout the south of India. The large salt-works at Bychubal, near Surapur, have already been mentioned (page 253). Much common salt is made at Surjapur, three miles east of Ling Sugur, from the waters of the Hiralla naddi, as well as at many other places.

MEMOIRS

OF THE

GEOLOGICAL SURVEY

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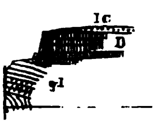

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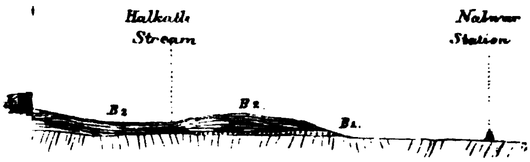

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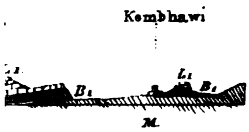

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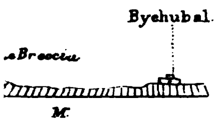

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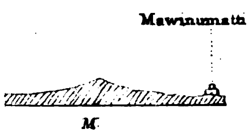

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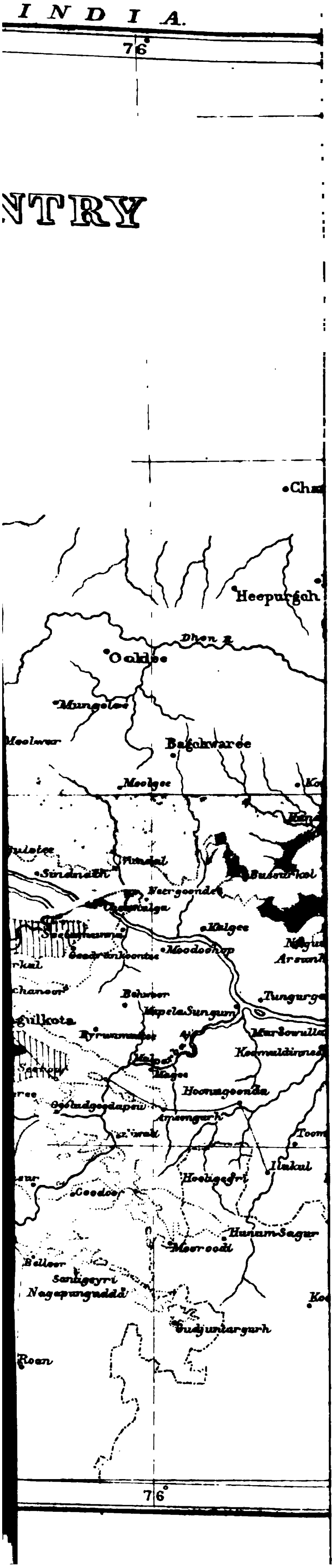
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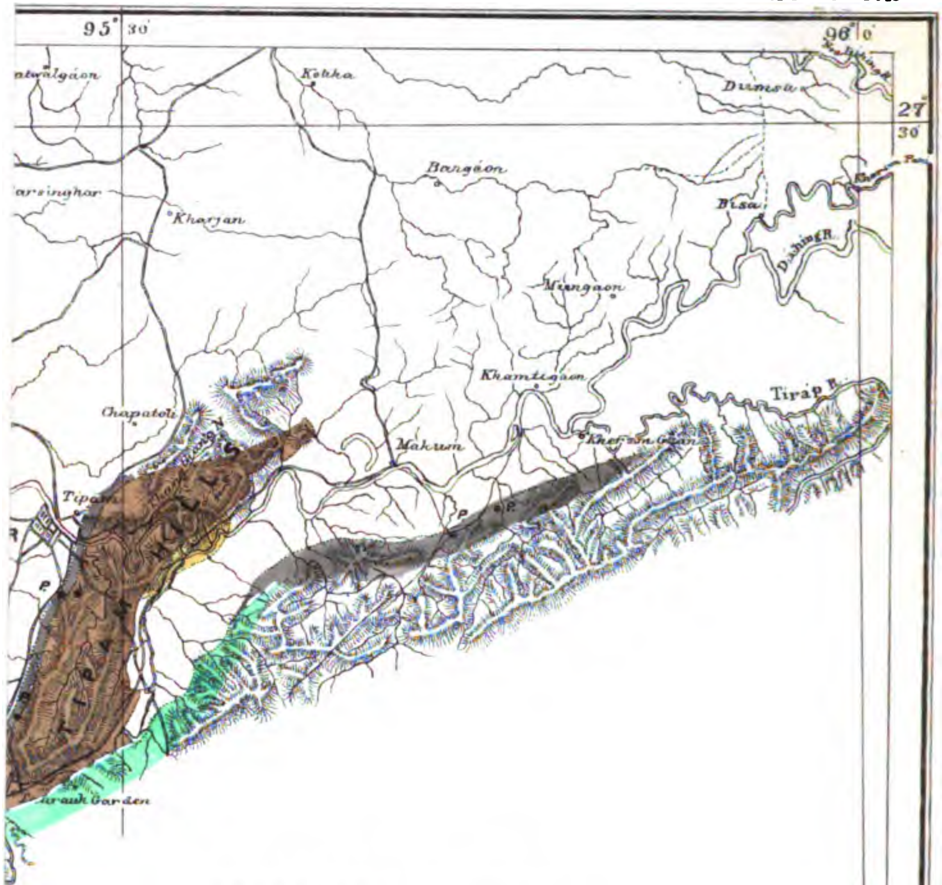

GEOLOGICAL SKETCH

of the

NÁGÁ HILLS

Immediately bordering

THE LAKHIMPUR & SIBSÁGAR DISTRICTS

Between the Tiráp & Disai Rivers

ASSAM.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

On the COAL-FIELDS *of the* NÁGÁ HILLS *bordering the* LAKHIMPUR *and* SIBSÁGAR DISTRICTS, ASSAM, *by* F. R. MALLET, F.G.S., *Geological Survey of India.*

CONTENTS.

In a country like Assam, where railways are as yet unknown, and roads available for wheeled traffic can hardly be said to exist, but where there are innumerable streams, some navigable throughout the year, and others for a greater or less portion of it, communication is carried on perforce almost entirely by water.

Between the great alluvial valley of the Brahmaputra and the rest of India there is at present, and for many years, no doubt, there will be, practically, but one channel of communication, namely, the Brahmaputra itself. One of the most important steps, therefore, towards opening out the province lies in the improvement of the existing means of navigating that river. Amongst other impediments now in the way of economical steam communication, one of the greatest is the necessity for carrying Bengal coal up stream, not only for the entire upward voyage, but for the return also: a thousand miles of river carriage, in addition to railway charges from Rániganj to Calcutta, raises the cost of the fuel at the head of the navigation to more than ten times its value at the mines. The great advantage which would accrue from a steady supply of Assam coal on the upper part of the river has long been admitted. Hitherto, however, that coal has only been worked on the most trifling scale, and in a desultory way, so that even the small supply which is sometimes procurable at Dihing Mukh cannot be depended on by the steamers. The projected branch line, again, from the Northern Bengal Railway to Goálpára will, if carried out, lend still greater importance to the fuel question in Assam.

The Nágá-hill coal-fields occur at intervals along the lower ranges which form the southern border of the Lakhimpur and Sibságar districts; the distances from the Brahmaputra varying from twenty-five to thirty-five miles in a straight line, or from forty to a hundred and fifty by the lines of river-carriage. Whether, therefore, the coal be conveyed to the main river down one or other of the affluent streams, or by a canal or tramway constructed for the purpose, it is a necessary preliminary to any systematic working to determine where, taking considerations both of mining and of subsequent carriage into account, the coal can be most economically raised. It was to investigate this point that, on the requisition of the Assam Government, I was directed to take up the examination of the above-mentioned ground.

The expedition, under the civil command of Mr. Goad, Superintendent of the Lakhimpur Police, started from Dibrugarh on the 22nd of

November 1874, and during the progress of the survey in the hills east of the Disang, I had the advantage of that officer's cordial co-operation. During the remainder of the cold weather of 1874-75, and the early part of the following season, Mr. Coombes, Superintendent of the Sibságar Police, was in charge, and later on Captain Latouche, Assistant Commissioner at Jorhát; towards the close of the season, charge was finally transferred to Mr. Pughe, then Superintendent of Police at Sibságar. To all of these officers I have to express my obligations for their endeavours to smooth away, as much as possible, the difficulties of surveying in a country where difficulties are exceptionally numerous.

History of Coal and Petroleum discoveries in Upper Assam.*

Lieutenant R. Wilcox, 1825-28.

The existence of coal in Upper Assam has been known from the earliest period of British occupation of the province. The first recorded notice that I am aware of is by Lieutenant Wilcox, who, in April 1825, accompanied a party of the 46th Regiment up the Disang river to Borhát. He remarked that the hills in the neighbourhood of that place consist of grey and yellow sandstone, and states that "coal is found at no great distance," but he gives no details as to its mode of occurrence, or the exact locality in which it had been discovered.

In a subsequent expedition up the Dihing river, Lieutenant Wilcox observed a seam of coal in the bed of the Buri Dihing at Súpkong, near which petroleum rises to the surface. Far to the eastward the same explorer again observed "thin strata of coal alternating with blue clay in the sandstone rock" on the north bank of the Dihing near Tumong Tikrang, a village south-south-west from the snowy peak of Dapha Bum.†

* East of the Dhansiri River.

† Asiatic Researches, Vol. XVII, pp. 322, 415, 420.

One of the earliest discoveries of coal was that in the Saffrai, and so long ago as 1828 a considerable quantity was actually raised by Mr. Bruce, who had been sent there for the purpose by Mr. D. Scott, Commissioner of the North-East Frontier. Mr. Bruce, with a party of 100 men, ascended the river in canoes during the rains, and commenced operations on a seam which he describes as being 24 cubits (36 feet) thick, with but one thin parting of shale. 5,000 *mans* were quarried and a large quantity loaded into the canoes, but the difficulties of the navigation were so great, owing to the swiftness of the current, the rapids and sharp turnings, that four canoes were lost going down stream. The remainder of the coal was brought in safety to the Brahmaputra and a boat-load despatched to Calcutta for trial, where it was pronounced to be equal to English coal and "the best ever found in India."*

Mr. C. A. Bruce, 1828.

Lower down stream than the above-mentioned bed, Mr. Bruce observed no less than eight other outcrops. The coal in one of these was said to be 12 cubits and in another 25 cubits thick (18 feet and 37 feet 6 inches, respectively). Some coal was raised from both of these; but being surface stuff that had been injured by weathering, it was found to be inferior to that quarried from the 36-feet seam.

Mr. Bruce also visited some low hills not far from the river, where iron ore was at that time extracted and smelted by the Assamese, the produce being worked up into *dhaus* for exchange with the Nágás for cotton, &c. He observed petroleum springs in more than one locality.

Coal and clay-ironstone were also found at Tiru Ghát—the Tiru being a stream which joins the Saffrai on the left bank.†

The existence of coal in the 'Nambua' (Námbar), a stream which joins the Dhansiri some miles south of Golághát, was pointed out in 1837 by Mr. Brodie, who

Mr. Brodie, 1837.

* Jour., Asiatic Soc., Bengal, Vol. IX, p. 213

† "Report of a Committee for the investigation of the coal and mineral resources of India, for May 1845," p. 113. Also Journal, Asiatic Society, Bengal, Vol. VII, p. 951.

picked up loose pieces "of good quality," but the position of the bed *in situ* was then unknown.*

Lieutenant H. Bigge and Dr. Griffith, 1837.

In 1837 Lieutenant Bigge and Dr. Griffith, while exploring the banks of the Námrúp, about nine miles east-south-east from its junction with the Buri Dihing in the Singpho country, discovered "a most valuable seam of coal in the bank of the river; the upper seam was about 3 feet in depth,† the centre one 9 feet, and a lower one of 3. * * * We loaded a small boat with this coal and sent it down to our camp for trial, when it was found to be an extremely good coal, burning with a strong flame and heat, and very lasting, but from the smell, containing a great quantity of sulphureous matter. It does not burn entirely away, but makes a large portion of cinder, and is, I should say, a very valuable description of coal." Some of the coal, in which the structure of the original wood was plainly visible, appears to have been lignite, and was not improbably from fossil stems in the Sub-Himalayan rocks. The remainder was doubtless coal from true beds, but Lieutenant Bigge's statement, that the former variety passes downward into the latter, is certainly incorrect.‡

Major White, 1837.

Major White at the same time discovered several springs of petroleum close to the camp on the Námrúp river, which had hitherto been unknown to Europeans, and apparently almost unused by the neighbouring Singphos.§

Captain S. Hannay, 1837-38.

The Jaipur coal appears to have been first examined, if not discovered, by Captain Hannay in 1837-38. On the 1st February of the latter year he reported having found several outcrops, and also noticed the occurrence of clay iron-ore,

* Journal, Asiatic Society, Bengal, Vol. VII, p. 950.

† Thickness?

‡ Journal, Asiatic Society, Bengal, Vol. VI, p. 243.

§ Journal, Asiatic Society, Bengal, Vol. VI, p. 243.

some of the masses of which required two men to lift them. The remains of old workings from which this ore had been extracted in former years were still visible. Captain Hannay also observed petroleum rising from some of the coal outcrops.* At the time of writing he had already commenced clearing a large seam, one mile and a half south-east from Jaipur. The particulars regarding the manner in which the coal occurs, and how he worked it, are described at length in a subsequent letter dated 15th September†; 1,050 *mans* of coal were raised altogether, of which upwards of 800 *mans* were sent to Dihing Mukh at a "total expense" of Rs. 96-5-6, or rather less than 2 annas a *man*. This sum, however, does not include any allowance for supervision, which was performed by Captain Hannay himself.

Out of the above quantity, a boat-load of 224 *mans* was sent to Calcutta for trial. The coal was reported on rather unfavorably as inferior to that previously sent by Mr. Bruce from the Saffrai, and as containing a considerable quantity of sulphur; for steam purposes 40 *mans* were found to do the work of only 32 *mans* of Burdwan coal. As pointed out, however, in the Coal Committee's report, the deficiencies of a first sample, taken from the outcrop of a single bed in a new and extensive field, ought not to be allowed too much weight.‡

Captain Jenkins, 1837-38.

While Captain Hannay's excavations were in progress, more definite information was gained by Captain Jenkins respecting the coal in the Disang, the existence of which had been previously indicated by Lieutenant Wilcox. The first seam met with was in the channel of the river, about a mile above the village of Borhát, and is described as about 8 feet in thickness; another was found about a quarter of a mile distant in the banks of a little water-course, and was traced at intervals for about 200 yards, throughout which distance it appeared to maintain a thickness of several

* Journal, Asiatic Society, Bengal, Vol. VII, p. 868.

† Ibid., p. 952.

‡ Journal, Asiatic Society, Bengal, Vol. VII, p. 954.

feet. The coal in both these beds appeared to be of the first quality, and favorably situated for working as well as for transport, so far as the waters of the Disang permit; but Captain Jenkins pointed out that "this stream is barely navigable for laden canoes of small size in the dry weather, although in the rains it has a depth of water sufficient for large boats, and its stream is nowhere impetuous." The last statement is not strictly accurate, as there are several rapids in the first few miles below the debouchure of the river from the hills.

Close to the second outcrop several small springs of petroleum were observed, from which the oil flowed into the pools in the water-course, and four or five *sers* were collected in a few minutes by Captain Jenkins' servants.*

Report upon the coal beds of Assam. (Submitted to Government by the Coal Committee as a supplement to their first printed report.)

This report contains a *précis* of all the information available up to date on the coal of Assam. The Committee point out the advantageous positions of both the Jaipur and Borhát coal seams with respect to water carriage, deciding between the two in favor of Borhát on the whole, 1*stly*, on account of the coal being closer to the river, and 2*ndly*, from the shorter water carriage to Disang Mukh. Later investigations and more accurate maps have shown these conclusions to be incorrect, as the coal is equally near the river in both cases, and the distances to Disang Mukh are almost the same, what little difference there is being in favor of Jaipur. The Committee were of opinion that, in the then existing state of communications between Upper Assam and other parts of India, its coal could not be supplied in Calcutta at a cheaper rate than that from Bengal: they considered, however, that it might be advantageously used for the supply of the Ganges steamers, and furnished estimates to show that it could be delivered at the higher stations on the Ganges at lower rates than were then ruling for Burdwan coal.†

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* Journal, Asiatic Society, Bengal, Vol. VII, p. 169.

† Journal, Asiatic Society, Bengal, Vol. VII, p. 948.

In their second notice of the Assam coal,* the Committee record a fresh discovery of the mineral in the Disang river by Lieutenant Brodie in 1839: specimens were forwarded to them for examination, and proved to be of good quality. It seems that in 1840 the Assam Tea Company were about to establish a coal quarry in this situation with the intention of keeping a depôt supplied from it at Dikhu Mukh on the Brahmaputra. The Company at this time apparently had a quarry actually at work at Jaipur.†

Lieutenant Brodie, 1839.

Assam Tea Company, 1840.

Mr. Bruce, who examined the Saffrai in 1828, had received information of coal in the Dikhu, but its existence seems to have been first actually proved by Mr. Landers, Special Assistant to the Commissioner, who, in 1842, found two or three beds, and worked one of them, near the village of Námsáng, on account of Government; this seam was 6 feet in thickness. A further trial was subsequently made by the Assam Tea Company, who raised 1,000 *mans* of coal and tried it on board their steamer. Mr. Smith, the commander, pronounced it "the best he ever had on board a steamer, generating steam quicker without clinker, and far superior to any coal in Calcutta."‡

Mr. A. H. Landers, 1842.

Assam Tea Company, 1842-44.

The final report of the Coal Committee was published in 1845, in which, under the head of Assam, a digest is given of all the then existing information regarding the coal of that province. In their concluding remarks "on the carriage of Upper Assam coal to Bengal," an estimate is furnished of the cost at which it could be delivered by native boats at the depôts on the Ganges, the conclusion the Committee arrived at being, that about 8 annas a *man* would cover all expenses.

Report of a Committee for the investigation of the coal and mineral resources of India, for May, 1845.

* Journal, Asiatic Society, Bengal, Vol. IX, p. 213.

† Journal, Asiatic Society, Bengal, Vol. IX, p. 218.

‡ Coal Committee's Report for May 1845, p. 112.

In a letter to Major Jenkins written in 1845, Captain Hannay described his search in the neighbourhood of Jaipur for petroleum. His principal endeavour seems to have been to find a bituminous rock like that of Pyremont, a sample of which he had been supplied with by Mr. Piddington. In this he was unsuccessful, but he obtained some specimens of "earthy and indurated sandy asphalte" near a spot about two miles from Jaipur, called 'Nahor Dung',* where it was found along with ordinary oil. These specimens were no doubt of earth and sandstone impregnated with inspissated petroleum. In the same neighbourhood he also found a small quantity of impure limestone.

Captain Hannay, 1845.

Captain Hannay also appears to have visited the Námchik river. "At Namtchuk Pathár" (he writes), "near the mouth of the river, the petroleum exudes from the banks, and a bed of very fine coking coal runs across the bed of the Namtchuk. The hills here are also intersected by ravines, and in one spot an extensive basin or hollow is formed at some height, which contains muddy pools in a constant state of activity, throwing out, with more or less force, white mud mixed with petroleum. This is, indeed, a strange looking place, and I am told by the Singphos that at times there is an internal noise as of distant thunder, when it bursts forth suddenly with a loud report, and then for a time subsides."†

In the latter part of 1847, Major Hannay had two quarries open at Jaipur on opposite banks of the Dihing, and was of opinion that a supply of coal fully equal to the requirements of Government could be obtained from these if boats were forthcoming for its carriage. Unless, however, the requirements of Government at that time were very small, Major Hannay must have over-estimated the producing capacity of such quarries. He describes

Major Hannay, 1847.

* Nahor Pung.

† Journal, Asiatic Society, Bengal, Vol. XIV, p. 817.

the seam as 16 feet thick, including 10 feet of coal, and appears to have traced it for a distance of about 200 yards.*

Mr. J. Thornton, 1848.

In 1848, Mr. Thornton, Sub-Assistant Commissioner, was sent to the Dikhu valley to report on the practicability of supplying coal from thence for the use of the Government steamers. He appears to have seen one bed only, which was then being worked by a native contractor, and which he describes as being 10 feet thick, including 3 or 4 feet of coal. From traces, however, left by Mr. Landers, he conjectured that other beds existed at a lower level. That worked by the contractor was situated on the brow of a hill 1,400 feet high and distant 2¾ miles from the coal depôt on the river, with a hill 1,800 feet high intervening. Mr. Thornton stated that canoes of 15 or 20 *mans* can be taken up the rapids to the place then used as a coal depôt, in the dry season, and of 100 *mans* during the rains, and on the whole he was of opinion that the difficulties of supplying coal from the Námsáng hill, although great, were not insurmountable; a native who accompanied him to the quarry was willing to contract for the supply of coal at Gauháti for 8 annas a *man*.† As will be seen in the sequel, numerous beds, far more favourably situated than the above-mentioned, have been found since Mr. Thornton's time.

Mr. H. B. Medlicott, 1865.

Subsequently to 1848 I am not aware that anything of importance was done (although small quantities of coal were raised at times at Jaipur and Makum, as well as, I believe, in the Disang and perhaps other places) until 1865, when Mr. Medlicott was deputed to visit the coal-fields of Assam generally, including those with which the present report is concerned. After examining the Jaipur and Makum fields, he pointed out the advantages of the former with regard to position, in being actually on the river bank, and below the rapids which exist some miles higher up stream, and he also noticed the probability of finding other seams below those visible at the

* Journal, Asiatic Society, Bengal, Vol. XVII, pt. 1, p. 167.

† Journal, Asiatic Society, Bengal, Vol. XVII, pt. 1, p. 489.

surface. These advantages, however, he thought were outweighed by the superiority of the coal from the Makum field, which he considered, judging from the evidence then available, to be *the* coal-field of Assam.

In the Námchik river he observed three thick beds of good coal within a length of section of 200 feet, and was of opinion that the Makum coal, and that in the above mentioned river, belonged, beyond reasonable doubt, to the same band. The supply from this field he considered to be practically unlimited, but at the same time pointed out the difficulty of extraction to be anticipated owing to the high inclination of the seams. The age of the coal he regarded as most probably nummulitic. Finally, the neglect of the Upper Assam coal, notwithstanding its proved excellence, and the causes which had led to this, were reviewed, and suggestions made with reference to the system on which the coal lands should be leased out. At the time of Mr. Medlicott's visit the authorities of Sibságar stated that they could not undertake to protect his camp in the interior of the Nágá hills.* Hence no effective examination of the Názira coal-field was then possible.

Some details were also given respecting the petroleum springs, of which the most abundant visited were those near Makum. The copious discharge of gas and non-discharge of water being both favorable symptoms, Mr. Medlicott recommended that experimental borings should be sunk there to practically test the value of the oil accumulations.†

Mr. Goodenough, 1866-68.

About the same time an attempt was being made by Mr. Goodenough, a member of the firm of Mckillop, Stewart and Company, to utilise the petroleum of Assam. He appears to have been granted certain rights over a large tract of land on both sides of the Buri Dihing, extending from Jaipur to the effluence of the Noa Dihing. "The first of the systematic borings for oil was commenced at Nahor Pung in November 1866, but it does not appear to have been successful, and it was abandoned after having been sunk

* Memoirs, Geological Survey of India, Vol. IV, p. 395.

† Ibid, p. 387.

to a depth of 102 feet. In addition to several other hand-borings, a Mather and Platt's steam-boring machine was set working in the latter end of December, and a hole was carried down 195 feet; but, with the exception of a few signs of gas, there were no good results."

"While the borings at Nahor Pung were proceeding, others were begun at Makum. Oil was struck in one hole on the 26th March 1867 at 118 feet, and it immediately rose 74 feet in the bore, being 44 feet below the surface. About 300 gallons were drawn, after which it was found not to flow continuously, a circumstance which it was hoped would be remedied by sinking deeper."

"As many as eight holes seem to have been put down in the Makum area, and they were nearly all successful in tapping oil. The yield varied in each. In January 1868, 100 to 125 gallons a day were collected from No. 4, while 550 to 650 gallons were collected from No. 5. The action of No. 5 bore was intermittent. Pure water was spouted for 3 or 4 hours, then almost pure oil for 15 to 30 minutes, after which all action ceased for an hour, or sometimes longer; and then activity set in again."

In the paper from which these details are derived* Mr. T. W. H. Hughes gives a table shewing the time when the blows of oil commenced, how long it continued running, and the quantity yielded, from which it appears that at times No. 5 bore gave as much as 100, and even 150 gallons per hour, for many hours consecutively.

Notwithstanding these results, however, Mr. Goodenough was not successful in establishing a petroleum industry. Difficulty of transport seems to have been the main cause of failure, raising the cost, I believe, in Calcutta, to a figure at which the oil could not compete with that from Rangoon and America.

Mr. Hailey.
Assam Tea Company.

During recent years coal has been raised to some little extent in a desultory way, more especially in the Makum field by Mr. Hailey, and in the Dikhu Valley by the

* Records, Geological Survey of India, Vol. VII, pt. 2, p. 55.

Assam Tea Company; the out-turn, however, has been very insignificant. It cannot be otherwise on the system hitherto pursued of working by mere surface scratchings.*

* The following list includes all the geological papers, &c., referring to the area under discussion with which I am acquainted :—

1832. Memoir of a Survey of Assam and the neighbouring countries, executed in 1825-26-27-28, by Lieutenant R. Wilcox. Alludes to coal at Borhát and on the Dihing river. Asiatic Researches, Vol. XVII, p. 314.

1835. Further discovery of coal beds in Assam, by Captain F. Jenkins. Journal of the Asiatic Society of Bengal, Vol. IV, p. 704.

1837. Notice of the discovery of coal and petroleum on the Námrup river, by Lieutenant H. Bigge. *Ibid*, Vol. VI, p. 243.

1837. Topography of Assam, by John M'Cosh, Calcutta, 1837. Contains some brief notes, compiled from previously published papers, on the mineral productions of Assam generally, including the Nágá Hills.

1837. Report on the physical condition of the Assam tea plant, with reference to geological structure, soils and climate. By John M'Clelland, Esq., Assistant Surgeon, &c., Madras Journal of Literature and Science, Vol. VI, p. 423.

1838. Announcement of two new sites of coal in Assam (Borhát and Jaipur). By Captain Jenkins, Agent to the Governor General. Journal, Asiatic Society, Bengal, Vol. VII, p. 169.

1838. Note respecting the Jaipur coal. By Captain S. Hannay. *Ibid*, p. 368.

1838. Native account of washing for gold in Assam, by Monirám, Revenue Sheristadár Bar Bandári. Communicated by Captain F. Jenkins. *Ibid*, p. 621.

1838. Further information on the gold washings of Assam, extracted from Captain Hannay's communications to Captain Jenkins, Agent to the Governor General in Assam. *Ibid*, p. 625.

1838. Report upon the coal beds of Assam. (Submitted to Government by the Coal Committee as a supplement to their first printed report.) *Ibid*, p. 948.

1840 Report of the (above) Coal Committee. Contains a brief notice of the Assam coal. Journal, Asiatic Society, Bengal, Vol. IX, p. 213. Also Madras Journal of Literature and Science, Vol. XI, p. 370.

1841. Despatch from Lieutenant H. Bigge, Assistant Agent, detached to the Nágá Hills, to Captain Jenkins, Agent, Governor General, North-East Frontier. Contains notices of iron ore, hot springs and limestone in the neighbourhood of Golághát. Journal, Asiatic Society, Bengal, Vol. X, p. 129.

1841. A descriptive account of Assam, with sketch of the local geography. By William Robinson, Calcutta, 1841. Contains a chapter, compiled from previously published papers, on the geology and mineral resources of Assam generally, including some notices of the Nágá Hills.

1844. Extracts from a report of a journey into the Nágá Hills in 1844. By Mr. Browne Wood, Sub-Assistant Commissioner. Contains a few remarks respecting coal

II.—General Geological Notes.*

Crystalline Rocks.

Pátkai range.

Little is known of the mountain-mass at the head of the Assam valley, to the north-east, whence flows the sacred branch of the Brahmaputra. The range that trends thence to the south-east, between Upper Burmah and Assam,

* The chief object of our expedition being a purely economic one, little time was available for geological observation foreign to the main question. The Nágá Hills are covered by the densest jungle and unsafe to enter without the necessary encumbrance of a guard; no food can be obtained, and one is continually hampered by the difficulty of carrying supplies for a large camp; geological work is thus carried on under many disadvantages at any time. For more than half the time we were in the field, however, we were practically without map of any kind, Thornton's, published in 1849, being, as far as the Nágá Hills are concerned, absolutely useless. During the remainder, the new Topographical Survey Maps were available.

and limestone near the Jamuna falls, and the limestone and salt springs in the Námbar river. Journal, Asiatic Society, Bengal, Vol. XIII, p. 771.

1844. The Nágá tribes in communication with Assam, by John Owen, Calcutta, 1844. Includes notices, derived from previously published papers, respecting the mineral products of the Nágá Hills.

1845. Analysis of lignite from Assam by H. Piddington, Esq., Journal, Asiatic Society, Bengal, Volume XIV, page lxxxv.

1845. Report of a Committee for the investigation of the coal and mineral resources of India, for May 1845. Calcutta, 1846. This was the Committee's final report.

1845. On the Assam petroleum beds, by Captain S. Hannay. Journal, Asiatic Society, Bengal, Volume XIV, page 817.

1848. Extract from a memoir of some of the natural productions of the Angámi Nágá Hills, and other parts of Upper Assam, by J. W. Masters, Esq. (communicated by J. W. Bushby, Esq., Secretary to the Government of India). Journal, Asiatic Society, Bengal, Volume XVII, Part 1, page 57.

1848. Extracts from letters from Major Hannay respecting the Jaipúr coal.—*Ibid*, Part 1, page 167.

1848. Correspondence regarding the coal beds in the Námsáng Nágá Hills, communicated by Captain T. E. Rogers, Superintendent of Marine. *Ibid*, Part 1, page 489.

1851. Analysis of coal and of galena from Assam, by H. Piddington, Esq., Journal, Asiatic Society, Bengal, Volume XX, page 366.

is known as the Pátkai. Its extension, or representative, further in the same direction, north of Manipur and Cachar, is known as the Barail ridge. Here it seems to be in very intimate relation on the south with the almost abutting ridges of the Arracan system, the same formations being seen to bend abruptly from the steady north-easterly strike of the Pátkai into the equally steady southerly trend of the contiguous ranges.* On its northern flank the Barail ridge passes close along the south-east margin of the Shillong plateau—a name proposed by Mr. Medlicott for the continuous, though deeply eroded, table-land commonly known as the Jaintiá, Khási and Gáro hills, separating Lower Assam from Eastern Bengal.†

* Journal, Asiatic Society, Bengal, Vol. XLIV, pt. 2, p. 210.

† *Vide* Mr. Medlicott's reports on the coal of Assam (Memoirs, Geological Survey of India, Volume IV) and the Shillong plateau (*Ibid*, Volume VII).

1853. Account of a visit to the Jaglu and Sísí rivers in Upper Assam, by Captain E. T. Dalton, together with a note on the gold fields of that province, by Major Hannay. *Ibid*, Volume XXII, page 511.

1856. Notes on the iron ore statistics and economic geology of Upper Assam, by Lieutenant-Colonel S. F. Hannay, communicated by the Government of Bengal. *Ibid*, Volume XXV, page 330.

1859. Note on recent investigations regarding the extent and value of the auriferous deposits of Assam, being abstracts of reports by Captain E. T. Dalton and Lieutenant-Colonel S. F. Hannay, dated October 1855. Memoirs, Geological Survey of India, Volume I, page 90.

1865. The coal of Assam; results of a brief visit to the coal-fields of that province in 1865; with geological notes on Assam and the hills to the south of it, by H. B. Medlicott, A. B., F. G. S, Deputy Superintendent, Geological Survey of India. *Ibid*, Volume IV, page 387.

1874. Petroleum in Assam, by Theodore W. H. Hughes, A. R. S. M., F. G. S., Geological Survey of India. Records, Geological Survey of India, Volume VII, page 55.

1875. Proceedings of a Committee assembled by order of His Excellency the Governor General in Council, under date the 28th January 1874, to consider and report on the best means of improving the steam service on the Brahmaputra, and the water communication with Upper Assam. Contains some remarks respecting the coal of Upper Assam. Assam Gazette, 17th April 1875.

1875. The evidence of past glacial action in the Nágá Hills, Assam, by Major H. H. Godwin-Austen, F. R. G. S., F. Z. S. Journal, Asiatic Society, Bengal, Volume XLIV, Part 2, page 209.

Crystalline rocks apparently not largely developed in Pátkai.

The known coal-fields of Upper Assam occur, either close to, or not far from, the plains, along the skirts of the Nágá and Singpho hills which constitute the northern flanks of the Pátkai. Little is known of the geology of the interior of these hills. From the boulders and pebbles brought down by the streams, however, it may be inferred that the rocks north of the water-shed are, in the main, sedimentary, and that crystalline rocks (or at least the harder varieties of such), if present, are not largely developed.

Pebbles of crystalline rocks are found in the Dihing, and it is very probable that such rocks exist high up the course of that river towards the snows from which it takes its rise. Crystalline rocks are known to occur in the hills north-east of Sadiya, and may extend in a south-easterly direction towards the head-waters of the Dihing.

In the Dirak, a small stream which joins the Dihing about ten miles below Makum, amongst the mass of sandstone pebbles, are a few small fragments of gneiss and quartz-schist. There can be little doubt, however, that these are merely pebbles washed out of the sedimentary rocks: the ridge at the head of the Dirak is the continuation of that at Rangkatu where the rocks are sedimentary and strike parallel to the ridge. Between Rangatu and the plains, rocks of the same class only are met with.

I observed no debris of the older rocks in either the Disang or the Taukák, but in the Saffrai pieces of foliated and granitic gneiss, white quartzite and quartz-schist (the latter containing spangles of silvery mica) and hornblende rock are not uncommon, some of the lumps being nearly a foot in diameter. I have never seen any conglomeritic band in the newer rocks from which these could have been derived; and such conglomerate if present towards the head of the Saffrai must be of very local occurrence, as no similar fragments are to be found in the Taukák or Dikhu, the drainage areas of which adjoin that of the Saffrai on either side. The absence of such, however, also shows that if crystalline

rocks in situ do exist near the head-waters of the Saffrai, their extension must be very limited. It is difficult to understand how they could be brought in there only without considerable faulting.

No crystalline debris is to be found in the Dikhu, the Jánjí or the Disai; but it is abundant in the Dhansiri (including, amongst other varieties, numberless pebbles of grey translucent quartzite, derived no doubt from the Shillong series). Immediately west of the Dhansiri we come upon the great mass of metamorphic rocks which form the northern portion of the Mikir, Jaintiá, Khási and Gáro Hills.* The strike of the metamorphic-sedimentary boundary, if produced into upper Assam, below the alluvium, would, on account of the trend of the hills east of the Dhansiri, pass to the north of their base. Hence the absence of the former rocks along the skirts of these hills is not surprising.

Major Godwin-Austen mentions "contorted clay shales and schists" as appearing from beneath the tertiary rocks close to Japvo, a peak of the Barail range to the south-east of Sámaguting, nearly 10,000 feet high. But their extension yet remains to be traced.†

Cretaceous group.

The band of cretaceous rocks which overlie the metamorphic strata on the southern side of the Gáro-Jaintiá hills, also comes to an end at the Dhansiri, and no representatives of this group have hitherto been found to the east of that river. The furthest point to which they have been traced is the mouth of the Námbar, which joins the Dhansiri some miles above Golághát. They may exist beyond this underneath the alluvium, but they do not rise to the surface along any part of the base of the hills that has yet been surveyed.‡

* The difference in the rocks cut through is well shown at the junction of the Doyang and Dhansiri, the former of which brings down dark-grey, and the latter red, sand.

† Journal, Asiatic Society Bengal, Vol. XLIV, pt, 2, p. 210.

‡ A few miles west of Bor Pathár, in the Námbar, there is a bed of cretaceous coal, information of which I received from Mr. Coombes. This is probably the seam from which the fragments found by Mr. Brodie in 1837 were derived (p. 4). It appears to be some

Disang group.

Throughout the length of ground examined, or from the Námchik to the Disai (and, probably, considerably further in both directions) the general dip of the rocks is *towards* the axis of the range; seldom at low angles, generally at moderate or high ones. Occasionally it is reversed at a high inclination. In the low hills east of Jaipur, known as the Tipám range, we have an ascending section of the rocks in their normal order, *viz.*, coal-measures, Tipám and Dihing groups; but elsewhere the structure is less simple, the newer beds being juxtaposed to the older in a way that can only be explained by inversion or faulting. The evidence in favor of the latter view will be more conveniently discussed further on (p. 33). It is here only necessary to point out that, throughout a large portion of the area examined, the older groups are found towards the interior of the hills, and the newer nearer the plains.

To the south of the Tipám and coal-bearing strata, we find an extensive development of shales and sandstones, which I have provisionally called the 'Disang group,' one of the best sections I obtained of them being in the river of that name. They include—

b.—Naogáon sandstone.
a.—Grey shales.

About a mile north of Naogáon the Tipám sandstones dip at 60°, and then, with a sharply defined (faulted) junction, splintery grey shales come in, which are somewhat contorted, and dip rather irregularly at

feet in thickness, with a dip of 5°. The coal is brownish-black, with dark brown streak; breaks with a conchoidal fracture; does not soil the fingers, and contains disseminated grains of reddish-yellow resin. An assay gave the following result:—

Hygroscopic water	10·0
Volatile matter (exclusive of water)	29·2
Fixed carbon	28·6
Ash	32·2
	100·0

The coal does not cake and leaves a white ash.

high angles. These beds are seen for some distance up the river and have a considerable thickness: then, north-east and east of Naogáon they become interbanded with, and pass up into sandstones. The latter are grey, or greenish-grey; fine-grained and rather hard; they are mostly thin-bedded, with occasional layers of grey shale, but in some parts thick and thin beds are intermixed. It is of this rock that the Naogáon ridge is composed. Lower down stream, loose pebbles of sandstone of the same kind, intersected by thin seams of quartz, a sixteenth or less to one or two inches in thickness, are common, the quartz frequently having a finely columnar structure perpendicular to the walls of the vein. I have not seen such vein rock in situ, but it not improbably comes from the above-mentioned strata*.

In the Makum field, beds very similar to those on the Disang are found to the south of the coal, but the shales and sandstones are, perhaps, less clearly demarcated. Between the coal-measures south of Kerimgáon, and Rangkatu, these strata mainly consist of grey and brownish-grey shales (sometimes clunchy), with sandstones which are generally fine-grained, thin-bedded, and rather hard when unweathered.

West of the Disang, the grey shales are well seen in the Teok; and in the Chota Taukák a fine section is exposed, resembling that in the Disang; grey shales interbanded with more or less sandstone are succeeded by tolerably hard, fine-grained sandstone, in thinnish beds with some thick ones. Good sections are also found in the Saffrai itself, and in the

* Possibly some of the gold found in the rivers flowing from the Nágá hills is derived from these quartz veins. The Janglu or Joglo nadi in the Tipám range, and the Disai are said to have yielded the purest and best gold in former times, when washing was carried on to a considerable extent in Assam (Journal, Asiatic Society, Bengal, Vol. VII, p. 626, and XXII, p. 511). The upper part of the latter stream has not been examined geologically, but it is very improbable that it flows through rocks older than those of the Disang group, while the course of the former is almost certainly entirely over rocks of the Sub-Himalayan series. Some of the gold in the Disai may be from the quartz veins, but that found in the Janglu can hardly be otherwise than doubly derivative. This latter fact has also been observed in the Sivaliks of the north-west Himalayas, (Vol. III, pt. 2, p. 179.)

tributary stream which joins it north-west of Borgong. The shale-beds are grey or dark-grey, often rather clunchy, and sometimes exhibit what seems to be an imperfect cleavage. The lower beds are often arenaceous, and include occasional nodules of calcareous sandstone.

In the Jánji, and its tributary the Sánga ján, the shales are largely developed, with the same lithology as further east. They are grey; sometimes clunchy, sometimes splintery, with occasional beds of fine-grained, rather hard sandstone interstratified. Pebbles and boulders of sandstone of the Naogáon (Disang) type are washed down from the ridge south of the Sánga ján.

The thickness of the Disang rocks is very considerable; probably some. thousands of feet. They appear to contain no coal whatever, and differ lithologically from the coal-measures in other respects also. The Disang shales, although interbanded with sandstone, are still, in the main, shales throughout, while in the coal-measures, shale, sandstone and coal occur in frequent alternations. The more characteristic coal-measure shales, again, are more tenacious, less clunchy or splintery than most of those in the Disang beds, and they pass into carbonaceous varieties. The coal-measures contain nodules of clay ironstone also, which I have not observed in the older strata.

Age.

The distinctness of this large group of strata from the coal-measures being thus fairly established on petrological grounds, it can certainly be inferred that they are the older of the two—the coal rocks being undoubtedly covered by the Tipám sandstone. I have, however, little or no stratigraphical evidence in proof of this inferred relation. The group has been principally observed along the main fault, in contact with the Tipám sandstone, the ground to the south not having been visited. Where seen contiguous with the coal-measures, the junction is also presumably a faulted one.

This position, beneath rocks the most probable age of which is nummulitic, suggests the possibility that the Disang beds may be

representative of Mr. Theobald's 'Negrais group' in the Arracan range, with some of which strata they seem fairly to agree lithologically; the rocks have not, however, a very strongly marked or distinctive character in either province. But, judging from the uniformity of structure in the Arracan hills throughout the length of 250 miles yet examined, it would not be surprising to find the same beds extend as far as Assam.

Coal-measures.

Lithology.

The coal-measures consist of alternating shales, sandstones and coal, with a few thin calcareous layers. One of the best exposed and most characteristic sections of them that I have seen is to be found in a small stream which descends the hill-side west of Kongan, and runs into the Dikhu a little above Tel Pung. Like all the subsequent sections, it is given in descending geological order.

	Ft.	In.
Grey shale, seen	5	0
Blank	14	0
Rather thick-bedded sandstone, dipping E. 25 S. at 25° ...	15	0
Coal	1	6
Brownish-grey shale	13	0
Blank	7	0
Thin-bedded sandstone, with one or two beds of hard and tough magnesian limestone	6	0
Thick-bedded sandstone	12	0
Thin-bedded sandstone, with nodules of clay ironstone ...	4	6
Thick-bedded sandstone	4	6
Clunchy grey shale, with nodules of clay ironstone ...	3	0
Thick-bedded sandstone	8	6
Brownish-grey shale	7	10
Clunchy grey shale, with a few nodules of clay ironstone ...	7	0
Brownish-grey shale	3	0
Coal	0	7
Carbonaceous shale	0	8
Coal	0	3
Carbonaceous shale	0	7
Coal	0	3
Brown shale	0	3
Coal	0	1

	Ft.	In.
Brown shale	0	1
Grey shale, with a few *coaly* laminae	6	8
Grey, rather clunchy shales, with some nodules of clay ironstone, and three or four layers of hard and tough magnesian limestone near the top	38	0
Blank	10	0
Brown shale	1	6
Coal	0	9
Brown shale	0	5
Coal, dipping E. 20° S. at 25°	3	0
Coal, with some interbanded carbonaceous shale	1	0
Brown shale, with *coaly* laminae and nodules of pyrites ...	1	4
Brownish-grey shale	2	4
Blank	3	0
Grey clunchy shale	8	0
Rather thin-bedded sandstone, containing a few clay ironstone nodules	21	0
Blank	6	0
Rather thin-bedded, slightly false-bedded sandstone, somewhat shaly in part	64	0
Thick-bedded sandstone, containing a few nodules of clay ironstone	9	0
Brown pyritous shale	8	0
Rather harsh, thin-bedded sandstone, dipping E. 10° S. at 20°...	24	0
Thin-bedded, rather shaly sandstone	10	0
Blank	15	0
Harsh, dark-grey sandstone (one bed) with *coaly* laminae ...	2	4
Grey shale	4	6
Brownish shale	4	8
Blank	2	6
Shaly sandstone	2	6
Rather harsh, fine-grained, thin-bedded sandstone... ...	1	6
Thin-bedded sandstone interbanded with grey shale ...	3	6
Grey pyritous shale, with occasional laminae of *coal*; seen ...	8	0
	377	1

The strata above the uppermost beds in the section are badly exposed, but similar alternations probably exist for some hundreds of feet higher.

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The following section was taken in a little side stream near the head of the Tiru nadi, north-east of Kongan hill station:—

	Ft.	In.
Grey shale, seen	1	0
Coal (hard), dipping S. 20° E. at 80°	1	9
Grey shale	1	0
Blank, about	10	0
Coal (hard), with two partings of carbonaceous shale ...	2	0
Grey shale	3	0
Blank	23	0
Brownish-grey shale	6	0
Coal (hard), dipping S.-E. at 90°	3	0
Carbonaceous shale	0	3
Brown shale	0	3
Grey shale	1	6
Blank	14	0
Grey shale	5	0
Coal	1	3
Grey shale	0	6
Shales and blank	16	0
Carbonaceous shale	1	4
Grey and brown shales	3	0
Coal	0	10
Brownish-grey shale	1	4
Coal	1	3
Grey shale	1	0
Shales and blank, about	15	0
Brownish-grey shale	5	0
Coal (hard), dipping S. 30° E. at 70°	2	3
Brown and grey shale	1	6
Coal	0	6
Brown, with some carbonaceous shale	2	0
Grey shale, seen	3	0
	127	6

and so the section goes on for three or four hundred feet more (although less plainly seen), including at least a dozen more beds of coal under three feet thick.

The above sections are sufficient to illustrate the general aspect of the coal-bearing strata. The sandstones, it will be seen, include both thick and thin-bedded varieties, but more frequently the latter; they

often contain nodules of clay-ironstone, which are also found in the shales: the most common sizes are from that of a walnut to 8 or 10 inches diameter. Layers, also, of the same ore are occasionally interbanded. Large nodules, and beds a few inches in thickness, of impure limestone are sometimes met with amongst the sandstones and shales. There appears to be a passage from pure clay-ironstone, through calcareous varieties of the same mineral, into more or less ferruginous limestone. Nodules of limestone also occur at times in the coal itself.*

The grey and brownish-grey shales are very argillaceous, and, where circumstances favor their alteration, decompose into a very tenacious blue clay. The latter variety of shale passes by degrees into carbonaceous shale, and it in its turn into coal. Pyrites is present in some of the shale beds as well as in the coal, either scattered through them in nodules, or more minutely disseminated.

Coal seams.

The second section illustrates the frequency of coal seams in some parts of the measures, there being no less than eight in 130 feet, but none of them over a yard thick. Beds, however, greatly thicker than these are not wanting, 20, 40 and even more than 70 feet of actual coal having been measured in one seam. The bed, for instance, south-east of Leáp (Makum field) contains, 37 feet of coal at least (p. 39). The greatest yet found, however, is that in the Námdáng nadi, south of Rángring, which is over 100 feet thick, and includes at least 75 feet of solid coal (p. 42).

With regard to the lateral extension of the seams, there is evidence that many of them are persistent for considerable distances. In the Makum field, coal is visible in large quantity in every watercourse along the base of the hills between north and north-west of Wátto, or for more than a mile. It appears to be on the same horizon throughout, and to belong to one great seam, which, within the above limits, shows

* For analyses of clay-ironstones and limestones, *vide* pp. 91, 94.

no symptom of thinning out in either direction. It is not unlikely that the coal a mile to the eastward (south-east of Leáp) is the extension of this seam; but as it has not been traced in the intervening ground, the point is open to doubt. The outcrops north-east of Tikák and west of the same village, which are about half a mile apart, are also very likely exposures of one bed, although not demonstrably so. The seam in the Námdáng south of Rángring can be traced for some 300 yards up stream. Including partings, it is over 100 feet thick at one end of the visible outcrop, but at the other it is not sufficiently well exposed to show whether it has partially thinned out or not.

In the Dikhu valley, a comparatively thin seam near Tel Pung is traceable for a measured distance of about 300 yards, without any alteration in thickness sufficient to indicate a commencement of thinning out in either direction.

A—Outcrop 40 yards from Dikhu River.	Ft.	In.	B—Outcrop 200 yards from A.	Ft.	In.	C—Outcrop 310 yards from A.	Ft.	In.
j—Brownish-grey shale	2	6	j } Not seen.			j } Not seen.		
i—Carbonaceous shale	0	7	i } Not seen.			i } Not seen.		
h—Brownish-grey shale	0	8	h } Not seen.			h } Not seen.		
g—Carbonaceous shale	0	4	g } Not seen.			g } Not seen.		
f—Brown shale ...	0	10	f—Brown shale ...	1	6	f—Brown shale ...	1	6
e—Carbonaceous shale	2	0	e—*Coal* ...	0	6	e—*Coal* ...	0	9
d—Brownish-grey shale	0	9	d—Brown shale ...	0	10	d—Brown shale ...	0	5
c—*Coal* ...	3	4	c—*Coal* ...	3	7	c—*Coal* ...	3	0
						Coal, with some interbanded carbonaceous shale ...	1	0
b—Brown shale, with laminae of *coal* and nodules of pyrites ...	0	6	b—*Coal* interbanded with carbonaceous shale	1	0	b—Brown shale with laminae of *coal* and nodules of pyrites	1	4
a—Brownish-grey shale, seen	3	0	a—Dark brownish-grey shale, seen	1	6	a—Brownish-grey shale ...	2	4

These cases, although in none of them the bed has been traced for more than a portion of its entire extent, are sufficient to prove beyond doubt that many of the coal seams have a considerable degree

of persistency, quite sufficient for mining purposes. How far they actually do extend, and whether they may not be traceable for considerably longer distances, is a question yet remaining for solution.

In some instances the seams vary more rapidly, in their subordinate layers at least, although possibly they are not less persistent as a whole. The following sections of a seam below Námdáng (Dikhu valley) were taken at outcrops 70 yards apart:—

		Ft.	In.
j	Brownish-grey shale, seen	4	6
	Brown shale	1	6
i	—*Coal*	3	9
h	Carbonaceous shale	0	10
	Brown shale	1	0
g	—*Coal*	1	5
f	—Brown shale	3	0
e	—Carbonaceous shale	1	8
d	—Brown shale, about... ...	5	0
c	—Inferior *coal*, laminated and brittle at outcrop ...	5	6
b	—*Coal* with some layers of carbonaceous shale ..	2	6
a	—Brown shale, seen	0	8

		Ft.	In.
j	Brown and brownish-grey shales	15	0
i	—*Coal*	4	0
h	—Carbonaceous shale ...	1	3
g	—*Coal*	1	7
f	—Carbonaceous shale ...	0	3
e	—*Coal*	1	2
d	Brown shale	1	0
	Carbonaceous shale ...	0	6
	Brown shale, seen ...	5	0
c, b, a	Not seen.		

Thickness of coal-measures.

A rough measurement of the thickness of the coal-bearing group in the Dikhu valley indicated something like 2,000 feet; but this amount does not include the portion sunk below the surface at the faulted boundary. In the Jaipur region merely the upper beds are visible above the alluvium level. The thickness in the Makum field is not improbably considerably more than that exposed in the Dikhu valley.

Probable age.

The occurrence of the Jaipur coal in contact with rocks of the Sub-Himalayan series, and in the same general relation to them as are the lignite-bearing nummulitic strata of the Punjab, originally suggested to Mr. Medlicott

the possibility of the measures in question having the same age.* No fossils have yet been found in the latter except vegetable remains too badly preserved to allow of specific determination. Dr. Feistmantel who has examined those I procured, found them all to be impressions of dicotyledonous leaves, indicating a tertiary, or at earliest cretaceous age. In the Khási and Gáro hills, both cretaceous and nummulitic coals are known, which differ from each other markedly in their mineral character. The first is "compact, splintery, with smooth conchoidal fracture, and a woody sound when struck; a fine lamination is traceable, and there is commonly an irregularly prismoidal structure across the bedding. It has the further peculiarity of containing numerous specks and small nests of fossil resin." These marked characters are maintained within the region under description, at the Námbar (see note p. 17). The nummulitic coal "has constantly very much the aspect of ordinary bituminous coal—the cuboidal structure and the half stony sound when struck."† The Upper Assam coal agrees exactly in mineral character with the latter. This, no doubt, cannot be regarded as very strong evidence, but it is at least suggestive.

The general lithology of both the cretaceous and nummulitic formations varies so much in the Khási hills as to afford no reliable means of comparing them with the Upper Assam rocks. It may be remarked, however, that the small development of calcareous strata in the Upper Assam measures cannot be allowed much weight as against their nummulitic age. Although limestone is generally one of the most important rocks amongst the Khási nummulitics, it is entirely absent from them over some areas. At Cherra, for instance, it is largely developed, but thins out completely to the north, and very nearly so to the east in the Gáro country.‡

There is, however, a notable point of contrast between these Assam measures and the known nummulitic coals. In north-western India the coal-bearing band occurs at the very base of the nummulitic group.

* Vol. IV, p. 416. † Vol. VII, p. 175. ‡ Vol. VII, p. 163.

In the Khási region, too, the great mass of the distinctively nummulitic strata is above the coal. In Upper Assam, on the contrary, there is a closely transitional relation of the coal-measures with the great sandstones of characteristic Sub-Himalayan type. Thus it would almost seem as if this great coal formation may even be of middle tertiary age.

Tipám group.

Lithology.

The junction of the coal-measures and Tipám beds, as seen in the Dihing and Disang, is fairly well defined. Some thick beds of sandstone of the Tipám type do occur amongst the lower strata near the top, but, in ascending the stream, a few yards above the last of the grey and brown shales with carbonaceous layers, &c., we come to thick-bedded sandstones in great force. These conform sensibly in dip and strike to the coal-measures, which they overlie at a high angle.

Above the junction, fine sections are exposed in both rivers. Thick-bedded and massive, frequently false-bedded, sandstones make up the great bulk of the strata. They are rather soft, and graduate from a somewhat coarse to a fine-grained rock, and into earthy sandstone. The usual colors are greyish-white speckled with black, speckled grey, and yellowish. Under the lens, the constituents are generally found to be quartz with some felspar, and dark specks like hornblende. Here and there amongst the sandstones beds of clunch are interbanded, of various colors—greenish-grey, green, purple and red, the last being often mottled with yellowish white. The clunch beds are very subordinate to the sandstones, although occasionally bands of some thickness are met with. In the Disai and the (Jánji) Tiru* the sandstones frequently pass into grey sandy clays, which are sometimes mottled.

Ferruginous bands are sometimes seen. South of Charaido and at Dholbagán there are low hillocks covered with clay, through which,

* There are two streams of this name; one a tributary of the Jánji, the other of the Saffrai.

here and there, blocks appear of a tough conglomeritic sandstone, containing small rolled pebbles of quartz and hornstone, and including little cavities more or less completely filled with hydrous iron oxide. The most ferruginous parts of the rock pass into a very impure, arenaceous cellular limonite. The continuation of this band is found in the low swelling ridge, just south of the Dhodar Alli, between the Saffrai and Taukák, on which the Náphuk and other tea gardens are situated. It is not improbably, also, the continuation of this rock in the opposite direction that is met with on the ascent of the first range of hills south of Giliki Guard.

A thinner band of similar rock is found in the Dikhu valley close to the junction with the coal-measures, as well as on the summit of the ridge to the north of the Sánga ján. In the latter locality it is associated with a coarse sandstone, such as is occasionally met with in the Tipám group, made up in part of quartz grains as big as peas.

Seams of coal are not altogether unknown in the Tipám beds, although they are very infrequent and of insignificant thickness. Thus, on the bank of the Disai, a three-inch layer of flakey coal was observed in clunchy strata, and in the Dukona nadi, south of Giliki Guard, there is a bed very similar in appearance to those in the true coal-measures, although included in strata belonging, almost beyond doubt, to the younger group. There is about two feet six inches of coal, split up into several layers by interbanded shale.

Besides the above true seams, layers of 'coal conglomerate,' or conglomeritic sandstone containing rolled pebbles of coal from the coal-measures, are of not very infrequent occurrence; as in the (Jánji) Tiru, Saffrai, and Dabbo.

Silicified wood occurs in great abundance, numberless pieces of it being washed down the streams which traverse the Tipám beds. More or less completely carbonised stems of wood, in which often some of the vessels are filled with pyrites, are common near the top of the group. They

are also met with lower down, but less abundantly. There, the general silicification seems to have been more complete.

Thickness.

The thickness of the group is very great. From the lowest beds overlying the coal-measures north of Jaipur, to the base of the Dihing conglomerates near the mouth of the Námsáng nadi, is about four miles in a line perpendicular to the strike. The average dip, of probably 20 to 25 degrees, would therefore indicate in this section an accumulation of some seven to nine thousand feet.

Dihing group.

At the bend of the Dihing, three-quarters of a mile below the mouth of the Námsáng, the massive, false-bedded Tipám sandstones include short, irregular bands of coal-conglomerate and pieces of semi-carbonised wood. Somewhat higher stratigraphically, at the mouth of the Námsáng, such layers of conglomerate are well seen, and here there is much wood also. The pebbles are, naturally, of the harder kinds of coal, and are mixed with a few others of sandstone and small ones of quartz and hornstone. Some layers are made up almost entirely of coal, but most of the rock contains a good deal of arenaceous matrix, and is friable and rusty. The wood is mainly in a semi-carbonised condition only. It has a brown color, and more or less retains the toughness of wood. In part, however, especially in the outer portions of the stems, it is black and brittle. Other parts, again, chiefly the central ones, are more or less completely silicified (although still retaining their dark carbonaceous color) so as to strike fire with the hammer. Both the silicious and carbonaceous portions frequently have many of the vessels filled with pyrites. Large pieces of such wood are very common in these beds, one log I measured being a foot in diameter and 10 feet long.

The coal conglomerate extends along the south-eastern border of the Tipám range as far as the Janglu nadi. The continuation of the section is well seen in the reach of the Dihing above the Nára Latta nalla, where

the above rock is covered by a considerable thickness of alternating conglomerates and clays containing occasional pieces of fossil wood—

	Feet.
Mottled red and greenish sandy clay, with two or three irregular layers or nests of pebbles	20
Conglomerate	25
Mottled red and greenish sandy clay	2
Conglomerate	4
Blue sandy clay	5
Conglomerate	10
Mottled red and greenish sandy clay	10
Blue sandy clay	5
Mottled red and greenish sandy clay	5
Conglomerate with two or three irregular layers of clay ...	6
Blue sandy clay	15
Conglomerate	4
Grey and brown sandy clay	7
Conglomerate	3
Mottled red and green sandy clay	4
Blue sandy clay	10
Conglomerate	10
Blue sandy clay	15
Conglomerate	8
Blue sandy clay	2
Conglomerate	10
	180

The conglomerate beds are composed of well rounded pebbles, varying in size up to some inches diameter, of fine-grained, rather hard sandstone, mostly greenish-grey in color, and identical in appearance with the Naogáon sandstone of the Disang group. The pebbles make up almost the entire rock, with but little matrix, although sufficient to cement them firmly together. The various layers of conglomerate and clay are rather irregular, varying rapidly in thickness, but are well demarcated from each other.

Below the section given, the beds are less clearly exposed, but similar alternations seem to extend as far as the coal conglomerate, perhaps 100 to 200 feet in vertical thickness, or 300 to 400 including the section

itself. The total thickness of the group is possibly much greater, but the rocks above the section are completely covered.

Recent conglomerate and clay, very similar in appearance to the Dihing beds, cover them in places, but the latter dip at about 20°, the recent beds resting on them horizontally and unconformably.

Beds, perhaps referable to the same epoch as the Dihing conglomerates and clays, are met with in some of the rivers to the westward, but being overlaid by alluvium, they are not exposed over any considerable area. In the Taukák, some distance north of the hills, beds of blue clay with an occasional band of coarse, but slightly consolidated sandstone, are exposed in the river banks. These are generally horizontal, but dip locally at 5 to 10 degrees. They may be recent. In the Saffrai the highest beds visible, next the coal-measures, are of conglomeritic sandstone with coal pebbles, perhaps on the same horizon as that in the Dihing, and therefore just at the base of the strata in question. In the Dhansiri also, about half-way between Bor Pathár and the Námbar, some horizontal conglomerate and sandstone are visible which contain abundance of silicified wood, some of the stems being a yard in diameter and four or five feet long.

Age of Tipám and Dihing groups.

That the Tipám and Dihing beds belong to the great 'Sub-Himalayan' series, which stretches along the entire base of the Himalayas, with, as far as we know, hardly a break from the Indus to Assam, does not admit of any doubt. North of Dibrugarh, Mr. Medlicott found the series in full force, consisting, as it also does in British Sikkim and the Punjab, as well as in the Nágá Hills, of a great accumulation of soft massive sandstones with occasional partings of clay, and passing above into great beds of conglomerate.* The similarity in the section at once suggests that the Tipám and Dihing groups may be, as they probably are, the Assam representatives of the 'Nahan' and 'Sivalik' groups of the Punjab. But with so many long gaps across which the rocks

* Vol. III, pt. 2, p. 114—IV, p. 393—XI, p. 45.

have not been traced, it is safer not to take this for granted, and to adopt local provisional names.

The abundance of silicified wood in the Tipám rocks, and its nature, suggest the question whether these rocks do not admit of correlation with Mr. Theobald's 'fossil wood group' of Pegu. Dr. Feistmantel examined more than a dozen specimens of silicified wood, which I collected from the former in different localities, and found them to be all exogenous and of one species, apparently belonging to the order Asclepiadeæ, and similar to wood brought by Mr. Theobald from Pegu. Mr. Theobald states there is but one species of fossil exogenous wood in the province.* But while he assigns a Pliocene age to the fossil wood group, the Nahuns are considered to belong to the Miocene epoch. The former also would seem to be in a somewhat less consolidated state than the Tipám rocks, and beneath, intervening between them and the nummulitics, comes a very important series of beds, called by Mr. Theobald the Pegu group. In Assam, on the other hand, the Tipám strata rest directly on the coal-measures, for which a nummulitic age has been suggested, although on somewhat scanty evidence. Fossil wood occurs in the Dihing group as well as in the Tipám, and the former is perhaps more nearly the representative of the Burmese rocks, although the latter do not include conglomerates like those which form so marked a feature in the Dihing beds. But different conditions of deposition are not unlikely.

Faulted boundaries.

An important difference between the sections in the Dihing at Jaipur and at the Tiráp quarries was pointed out by Mr. Medlicott in 1865.† In the former the coal and associated shales are covered by the soft massive Tipám sandstones, but in the neighbourhood of the Tiráp they are overlaid by sandstones of a markedly different type. The very cursory examination then practicable did not allow of Mr. Medlicott's arriving at a definite conclusion as to the explanation of this want of uniformity. He pointed out that the difference might be due to the coal rocks in the two localities being on different horizons; to the absence of strata in one which are represented

* Vol. X, p. 252.

† Vol. IV, note p. 401.

in the other; to faulting; or to inversion in the Makum field (the Jaipur beds being clearly in their normal order): and judging from the evidence then available, he was inclined to the last view. The much more detailed examination I have had the opportunity of making of the various coal-fields has led me to a different conclusion. At Jaipur the coal-measures are so obscured that little is visible save the coal-seam itself (p. 49) with a few beds of shale, and the over-lying Sub-Himalayan sandstones, the measures being those at the very top of the group. The Tiráp coal I believe to belong to a lower part of the group, the sandstone overlying it being a portion of the measures themselves, and lying in normal (non-inverted) position. I have not found any trace of the synclinal structure, implied in the supposition of inversion, along the inner zone of coal-measures, nor will the facts now known allow of this interpretation.

There is some direct evidence of great faulting along this inner zone. In the Saffrai, for a mile or so below the junction between the Sub-Himalayan and coal rocks, conglomeritic sandstones containing rolled pieces of coal, &c., are visible at intervals, with a rather steady dip a little south of east at about 15°. Then, as we ascend the stream, we come suddenly on the coal rocks with an average dip of 60° or 70°. At the head waters of the Tiru, again, the Tipám strata at the junction, which is clearly defined, dip at a markedly lower angle than the coal measures, or 20° to 25°, while the latter are inclined at 70° or 80°. In the Dikhu the actual junction is not seen, but in the Sánga ján and the Jánji, except near the junction of the two streams where there is a small development of coal rocks, the Tipám and Disang groups are again in contact.

To the south of the coal-measures in the Dikhu Valley, we find (as noticed above) the Tipám beds again. The river here flows through a narrow rocky gorge in which they are finely seen, consisting of rather hard and sometimes coarse sandstone very thickly bedded, and showing false bedding in places. Many of the strata are over 20 feet thick. Towards the base there is some shale with thin carbonaceous layers interbanded. The bold way in which these rocks weather led me at first to question their

being Tipám, but the carbonaceous seams at the base, and the abundance of silicified wood which I subsequently observed washed out of them from the Chingan ridge, near the head waters of the Tiru, leave, I think, no room for doubt. They overlie the coal-measures, which therefore cannot be inverted, and the northern boundary of which must therefore be a fault. The occurrence of Tipám beds in force south of the measures shows that the northern boundary is not an original limit of deposition against a pre-existing escarpment.

The non-inversion of the coal-measures necessitates another fault between them and the Disang group in the Saffrai Valley, as well as between the latter and the Tipám beds north of Nángta. The same reasons also lead us to conclude that both the northern and southern boundaries of the coal-measures in the Jánji Valley are faulted ones.

In the Disai we have the measures flanked by Tipám beds on both sides. The fault along the northern boundary is very probably the continuation of the main fault to the eastward, but as the intervening ground, between the Disai and Jánji, has not been examined, the point is not beyond doubt.

In the Makum field I observed some massive sandstones, with greenish-grey clunch, of a very Tipám-like appearance, in the branch of the Námdáng which comes from Tuplong, and Mr. Medlicott found similar beds south of the coal rocks, and apparently (according to the dips) overlying them, in the Makum nadi. It would appear, therefore, that the Dikhu valley structure is repeated in this part of the Makum field. The main fault in all probability passes close to the base of the hills both here and further east, in the Námchik field. Sub-Himalayan beds with southern dip were found by Mr. Medlicott just north of the coal rock, in the latter area.

It will be seen, then, that according to the above interpretation, the Makum, Názira, Jánji, and probably the Disai, coal-measures, are in the same line of up-throw along the southern side of the main fault, while the same strata in the Jaipur field are in a different and outer line of upheaval.

III.—The Makum Field.*

Boundaries, &c.

The Makum coal-bearing area stretches along the outermost range, or rather outermost spurs, of the hills to the south and east of the small fortified post of that name. The measures extend down to the base of the hills, and the northern surface boundary of the field is therefore the edge of the alluvium: I have already explained that the main fault, by which the Sub-Himalayan are brought against the coal rocks, in all probability passes not far from the foot of the hills. To the south of the measures we have rocks belonging to the Tipám and Disang groups. My observations are not sufficiently numerous to enable me to color these, but the limit of the India-ink-tinted area is probably not widely different from the southern boundary of the field, to the east of the Námdáng at least.

The most easterly point to which the measures have been traced is south-east of Kerimgáon, but they very probably extend as far as the end of the ridge, where they would be cut off by the southern trend of the alluvium. In the opposite direction coal has been found in the Dirak nadi, but between that point and the Disang I have no observations. The western termination of the field therefore, and the geological lines between that and the Taurauk garden are conjectural.

The extreme points at which coal has been actually found, then, are thirteen miles apart, but the probable total length of the field is some miles more. All the most valuable seams yet known or worked are included in the area between the Tiráp and Námdáng. West of the latter stream but little is known of the field.

As is commonly the case, the hills conform in their longitudinal direction with the strike of the rocks, but they do not form a continuous

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* Twenty-four miles east-north-east of Makum lies the Námchik coal-field (Mem. Geol. Surv. Ind., Vol. IV, page 399), and beyond that again, the Námrup. These are, however, beyond the limits assigned to our exploration.

ridge, being cut through by several streams. East of the Námdáng their height above the plain is about 1,000 feet. The measures as a whole dip at rather high angles to south-south-east, and consequently most of the known outcrops are on the northern side of the hills. The dip sometimes, however, is in the reverse direction.

Coal outcrops.—In a nalla close to the path from Kerimgáon to Wátto, coal is seen (and has been worked) in several places, but only at intervals, no continuous section being exposed. Ascending the stream, the first coal seam dips north at 40°, but its thickness is not apparent. A little further up, in an old quarry, we have—

Tiráp quarries.

	Ft. In.	Ft. In.
Grey clunchy shale, seen	...	3 6
Carbonaceous shale and *coal*	0 8	
Coal, seen	6 8	

Dip north at 25°.

A little higher up is another quarry, but choked up so that only 1 foot 5 inches of coal is now visible. A little further still, in a third quarry, the following section is exposed:—

	Ft. In.	Ft. In.
Grey shale, seen	...	2 0
Carbonaceous shale	...	0 6
Coal, seen	3 0	

Dip north-east at 20°.

The total thickness of coal exposed in this nalla is about 14 feet.

In a nalla a little west of the above the following section is seen:—

	Ft. In.	Ft. In.
Rather soft, yellowish-white sandstone, seen ...	...	11 0
Grey shale	...	1 0
Blank	...	11 0
Grey shale	...	2 6
Coal, dipping east 20° north at 5°	9 0	
Blank	5 0?	
Brownish-grey shale	0 8	

	Ft.	In.
Coal	2	0
Blank	15	0?
Coal	2	0
Blank	3	0
Coal	5	0?
Brownish-grey shale	0	6
Coal	0	4
Blank	6	0
Coal	10	0?
Total visible thickness of *coal* ...	28	0?
" " " " shale ...	1	2?
Blank	29	0?
Total visible thickness of seam ...	58	6?

The 9ft. coal was being quarried in 1874-75.

In the next nalla to the west, a large quantity of coal is exposed.

Between Tiráp quarries and Leáp nadi.

In two places 8 feet of it is seen, neither top nor bottom visible: dip south-east at 5°. In the next, again, coal is also abundant, dipping north at 15.° In a nalla which crosses the Wátto-Manglang path, I estimated the coal at not less than 30 feet, dipping east-30°-south at 20°. In the Sipri nalla (a little west of the above path) 15 feet of solid coal is exposed in a cliff, neither top nor bottom visible: dip east-10°-south at 40°. Thus a large quantity of coal is visible at the base of the hills in every nalla for more than a mile to the westward of the Tiráp quarries. It appears to be on the same horizon throughout, forming one great seam with probably some minor ones also. No good section of the entire seam is anywhere visible, but I should estimate the average thickness of coal at not less than 25 feet. It is not improbably over 30. The dip is irregular, varying from 5° to 40°. It is mainly to north and north-east near the quarries, changing, further west, to south-east. Most of the coal is of the hard kind.*

* *Vide*, p. 78.

Leáp nadi.

In the Leáp nadi, where it leaves the hills, there is a section visible as follows:—

	Ft. In.	Ft. In.
i.—Grey shale, seen	...	7 6
h.—Blank	...	5 0
g.—*Coal*, dipping south 20° east at 35° ...	7 0	
f.—Brownish-grey shale, seen at intervals ...	...	30 0
e.—*Coal*, with partings of carbonaceous shale ...	2 0	
d.—Grey shale	...	4 0
c.—Grey shale and soft sandstone, seen at intervals	...	130 0
b.—*Coal*	4 0	
a.—Grey shale, seen	...	2 0

50 yards higher up stream the dip is reversed (the strata forming a synclinal), and the upper beds in the above section are again brought to the surface.

	Ft. In.	Ft. In.
h.—Grey shale, seen	...	3 0
g.—*Coal*, dipping north 30° west at 35° ...	7 0	
f. { Brownish-grey shale, seen at intervals ...	...	30 0
f. { Grey shale	...	4 0
e.—*Coal*	2 0	
d.—Grey shale, seen	...	5 0

The 7 feet seam is about 170 feet above the 4 feet, and both are of good coal.

South-east of Leáp.

At the foot of the hills, in a nalla south-east of Leáp, the following section is visible:—

	Ft. In.	Ft. In.
Brownish-grey shale, seen	...	35 0
Blank	...	18 0
Coal	2 0	
Blank	2 0	
Coal	8 6	
Blank	2 0	
Brownish-grey shale	4 6	
Coal	0 6	
Brownish-grey shale	0 4	
Coal	1 0	
Brownish-grey shale	2 0	
Coal	25 0	
Blank	...	9 0
Greyish, fine-grained sandstone, seen	...	4 0

	Ft.	In.
Total visible thickness of *coal*	37	0
" " " " shale	6	10
Blank	4	0
Total visible thickness of seam	47	10

Dip north at 45°; coal hard. A hundred yards distant in another nalla the seam is more obscurely seen, dipping north at 35°. It is very probably the continuation of that north of Wátto, which, if so, must have a lateral extension of at least two miles.

North-east of Tikák.

A few hundred yards north-east of Tikák on the northern slope of the hill, there is a section exposed comprising—

	Ft.	In.
Coal, seen	6	0
Blank	10	0
Coal, seen	9	6
Total visible thickness of *coal*	15	6
Blank	10	0
Total visible thickness of *seam*	25	6

Dip south-east at 30°; coal of medium hardness. Elevation above the plain 750 feet.* It was quarried to a trifling extent in 1874.

West of Tikák.

In a nalla just below, and west of, Tikák, the following section was laid bare by digging:—

	Ft.	In.	Ft.	In.
Brownish-grey shale, seen	...		1	0
Coal	5	0		
Lenticular layer of carbonaceous limestone ...	0	6		
Coal	4	6		
Brownish-grey shale	9	0		
Coal with one or two thin partings of carbonaceous shale	13	0		
Carbonaceous shale, seen	1	0		
Total visible thickness of *coal*	22	6		
" " " " carbonaceous shale ...	1	0		
" " " " shale &c., ...	9	6		
" " " " seam	33	0		

* This, and other heights subsequently given, were measured with an aneroid.

Dip, south-30°-east at 40°; coal of medium hardness. Elevation above the plain 900 feet. This coal is very likely the same as that north-east of Tikák.

West of Rángring.

In a nalla just below and west of Rángring a section is visible which includes—

	Ft. In.	Ft. In.
Greyish-white shale	...	2 0
Coal	11 9	
Grey shale	2 0	
Coal	10 0	
Blank	...	15 0
Fine-grained shaly sandstone	...	6 0
Blank	...	30 0
Fine-grained sandstone, shaly in part	...	20 0
Blank	...	6 0
Fine-grained, hard, thin-bedded, yellowish-white sandstone		7 0
Brownish-grey shale	...	1 3
Coal, dipping east 10° south at 40°	2 3	
Brownish-grey shale	...	1 6
Blank	...	13 0
Brownish-gray shale	...	2 0
Coal, dipping east at 35°	4 0	
Brownish-grey shale, seen	...	2 6
Total visible thickness of *coal* in main seam ...	21 9	
" " " " shale " " ...	2 0	
Total visible thickness of seam	23 9	

Dip of the main seam, east-10°-south at 35°; coal of medium hardness. Elevation above the plain 1,000 feet. It may be the same as the Tikák coal. A small quantity was raised from this outcrop in 1874-75. The 2′ 3″ coal, and upper half of the 4′ 0″ is similar to that in the main seam. The lower part of the 4′ 0″ is very hard and difficult to break in site with a pick.

Námdáng south of Rángring.

At the mouth of a small lateral nalla joining the eastern branch of the Námdáng south of Rangríng* the following section is exposed.

	Ft.	In.	Ft.	In.
Shaly sandstone, seen			8	0
Brownish-grey shale			1	6
Coal	4	0		
Brownish-grey shale	2	6		
Coal	4	0		
Brownish-grey shale	5	6		
Coal	18	0		
Brownish-grey shale	11	0		
Coal	21	0		
Blank	8	0		
Coal	13	0		
Brownish-grey shale	4	6		
Coal, seen	15	0		
Total visible thickness of *coal*	75	0		
" " " " shale	23	6		
Blank	8	0		
Total visible thickness of seam	106	6		

Dip, east at 50°; coal hard. The seam can be traced for some 300 yards up stream, having, a little beyond the above section, a south-western strike and vertical dip.

Owing to the thickness of this seam and the circumstances of its position, a greater quantity of coal appears to be within reach by open workings than in any other locality in the field that I have seen.

Lower down in Námdáng.

Some three hundred yards below the junction of the branches of the Námdáng, a thin seam exists, having a section as follows :—

	Ft.	In.	Ft.	In.
Brownish-grey shale, seen			0	9
Coal, dipping east 20° south at 50°	2	0	...	
Earthy sandstone, seen			1	6

* In the Námdáng about here there are some large loose blocks of a highly vesicular dark-grey slag, which has probably been formed during the combustion of some coal seam at the outcrop.

A quarter of a mile lower down there is another.

	Ft.	In.	Ft.	In.
Arenaceous shale, seen	...		4	0
Grey shale			2	6
Coal, dipping east 40° south at 60°	2	0	...	
Grey shale			2	0
Brownish shale, seen	...		4	0

On the left bank of the stream, where it leaves the hills, are two old coal quarries, now quite choked up. They are probably in different seams. The sandstone close to the more southerly of these dips south-east at 40°, and near the other east-10°-south at 15°.

S. of Jaihing.

In a nalla on the hill-side south of Jaihing, a seam is visible, of which, however, only 1 foot is exposed. Dip east 20° south at 60°.

Makum nadi.

A couple of miles above the debouchure of the Makum nadi from the hills, a 2-feet seam was observed, dipping south-east at 30°, and fifty yards further on another is obscurely visible.

Dirak nadi.

On the right bank of the Dirak where it leaves the hills, there is a seam having the following section:—

	Ft.	In.	Ft.	In.
Grey shale, seen	...		2	9
Coal	3	0		
Grey shale, seen	...		3	0

Dip about south-south-east at 80°; coal soft and crushed.

Quantity of available coal.

In coal-fields of limited extent, where the measures are nearly horizontal, a useful approximation to the quantity of fuel available may be obtained by multiplying the area by the mean thickness of the coal. But the circumstances of the Upper Assam fields render this method inapplicable. In all of them the measures have a high general dip towards the hills, and the seams must rapidly sink to a depth below which the coal could not be profitably worked. No doubt there are local foldings of the strata by which seams may be brought to the surface a

second time (as in the Leáp nadi), but this does not affect the question on the large scale. It is, therefore, only a narrow fringe along the outcrop that is of any practical value. Further, until much more has been done towards opening out the fields, it will be impossible to arrive at any just conclusion as to the total average thickness of coal in each; and hence it is impossible at present to form any reliable estimate of the total quantity of available coal. But failing this, if it can be shown that there is every prospect of a supply of coal equal to all probable demands for a long time to come, it will suffice for present purposes. This the information now at command enables us to do. A large amount of coal can be indicated which may be depended on with reasonable certainty, although the total available quantity may possibly greatly exceed this. The minimum quantity to be expected can be pointed out, but not the maximum.

In the eastern part of the field it will have been seen that there is almost certainly at least one very thick seam everywhere present from the Tiráp quarries to the Námdáng. Even supposing that the Tiráp seam does not extend west of Leáp—that it is lost by a fault or dies out, the latter of which suppositions is certainly not indicated by a thickness of nearly 40 feet where last seen—there is then the Tikák seam and that at Rángring, which is not improbably the same as the Tikák one, and further on the seam in the Námdáng. But it is quite possible that the Leáp may continue to the west below the Tikák, and the latter towards the east, and that there are thus at least two thick seams in the same part of the field. Taking into count, however, only what is actually known, we have the following measured thicknesses:—

	Ft.	In.
Tiráp seam north of Watto + seams in Leáp Nadi (25′ + 7′ + 4′)	36	0
Seam south-east of Leáp	37	0
Seam north-east of Tikák	15	6
Seam west of Tikák	22	6
Seams west of Rangring (21′ 9″ + 4′)	25	9
Seam south of Rangring	75	0
Average	35	3¼

Considering that in not one of the above sections (except of the minor seams of 7 and 4 feet) is the full thickness of the coal visible, it can hardly be above the mark to take the average thickness of the coal at 10 yards. With regard to the breadth of the workable fringe, we have, in some places, a local dip of the seams towards the north, which, if constant for any distance, would enable the coal to be advantageously followed into the hills towards the 'rise.' Elsewhere, again, the outcrops are several hundred feet above the plain, and facilities would probably present themselves for adit workings. But frequently it would be necessary to mine towards the deep. Taking it all round, then, the seams could probably be worked without any serious difficulty to a distance of 200 yards from the surface (measured along the seam). With an average dip of 40°, this would involve a vertical depth from the outcrop of less than 400 feet in the most unfavorable case of working towards the deep. This cannot be regarded as excessive even in Assam, considering that some of the Rániganj mines, where the low dip of the coal renders deep mining as yet unnecessary, have reached 250 feet, and that in Europe pits have been sunk to as much as 3,000. The distance, then, from the Tiráp quarries to the Námdáng being $5\frac{1}{8}$ miles, the cubic contents of the available known coal on the above estimate is $5\frac{1}{8} \times 1{,}760 \times 200 \times 10$ yards, containing over 18 million tons. Considering the difficulty of working such very thick and such highly inclined seams, a liberal allowance must be made for loss in mining. If this be taken at one-half, there remain nine million tons of marketable coal easily procurable.

In the above estimate no account is taken of other seams, which there can be no doubt exist, beside those already known, nor of the extension of the field itself to the west and east. These figures must therefore be taken as the smallest quantity that can reasonably be expected, but there are not sufficient data to estimate how much more may be anticipated.

IV. The Jaipur Field.

Limits of the field.

From an economic point of view, or with reference to water carriage, the Jaipur field is naturally divisible into two sections—the northern or Dihing, and the southern or Disang—but it is one geologically, the measures being continuous between these rivers.

The coal-bearing strata extend as a narrow fringe along the western edge of the Tipám hills, dipping at high angles (seldom less than 30° or 40°, and sometimes nearly vertical) beneath the Tipám sandstones. The boundary passes along the skirt of the hills, so that only the uppermost part of the measures is visible at the surface. The remainder is sunk below the alluvium level. The most northerly coal rocks known as yet are at Tipám tea garden, about three miles north-east of Jaipur. There can be little doubt that they extend further on—not improbably as far as the end of the range—below the Sub-Himalayan beds, as is, indeed, indicated by the numerous 'pungs' existent along the edge of the hills. But whether they rise above the alluvium level or not is undetermined. Between the Dihing and Disang the measures are visible in every nalla, and also close to Boruarchali, but on the path from Halua to Kulun Mutun they do not appear, the Sub-Himalayan strata being there in contact with the alluvium. On the northern side of Gujua Ting, a low detached ridge near the debouchure of the Teok from the hills, they are again apparent, in the same relation to the Tipám beds as further east, and this outcrop, eight miles south-west of Boruarchali, may be regarded as an outlier of the Jaipur field. Coal is also said to occur at the base of the hills in the Deodubi, a tributary of the Teok south-west of Kánugáon, but, owing to heavy rains and the consequent flooding of the stream, the bed of which forms the only path, it was impossible to approach the place at the time I was in the vicinity. In the Borján, a

stream south of Kánugáon, running parallel and close to the fault between the Sub-Himalayan and Disang rocks, I picked up one or two pieces of coal, which may indicate that the coal-measures are not wholly obscured along this line. The fragments may, however, have been washed out of the Sub-Himalayan coal-conglomerate (p. 29).

Tipám tea garden.

Coal outcrops.—During the cold weather of 1874-75, Mr. Greig, of Jaipur, to whom I am indebted for valuable information respecting the coal of that neighbourhood, discovered and cleared several outcrops. The most northern of these, near the edge of the hills at Tipám tea garden, has the following section :—

	Ft. In.	Ft. In.
Grey shale, seen		1 0
Coal, dipping W. 30° N. at 60° ...	1 8	
Grey shale seen		3 0

Two hundred yards south-south-west of the above, Mr. Greig cleared another with a section as follows :—

	Ft. In.	Ft. In.
Grey shale, seen		0 9
Carbonaceous shale	0 6	
Coal	0 9	
Grey shale	1 1	
Coal	1 4	
Grey shale	0 3	
Coal	1 1	
Grey shale	0 1	
Coal	0 8	
Grey shale	0 2	
Coal	1 0	
Grey shale	0 4	
Carbonaceous shale	0 9	
Soft grey earthy sandstone		1 6
Grey shale		0 6
Coal in seam	4 10	
Carbonaceous shale	1 8	
Shale	1 11	
Total thickness of seam	8 0	

Dip, east-20°-south at 60°. As in many other cases, the grey shale is altered at the surface into a tenacious blue clay.

Close to the last seam, and about 70 feet (stratigraphically) below it, Mr. Greig found another which has the following section:—

		Ft.	In.	Ft.	In.
l.	Grey shale, seen			2	6
k.	*Coal*	1	1		
j.	Brown shale	0	4		
	Grey shale	0	3		
	Brown shale	0	1		
i.	*Coal*	1	5		
	Brown shale	0	1		
	Coal	2	1		
h.	Brownish-grey shale	0	2		
	Grey shale	0	6		
	Brownish-grey shale	0	2		
g.	Carbonaceous shale with layers of *coal* ...	0	9		
f.	Brownish-grey shale			0	3
e.	Soft, fine-grained grey sandstone			0	6
a.	Grey, arenaceous, clunchy shale, seen			9	0

	Ft.	In.
Coal in seam	4	7
Carbonaceous shale	0	9
Shale	1	7
Total thickness of seam	6	11

Dip east-20°-south at 60°. The coal, at the outcrop, is very brittle, being cut up by jointing in two directions and by lamination planes; it contains nodules of pyrites.

The same seam was also exposed at 20 yards distance from the above—

		Ft.	In.	Ft.	In.
l.	Grey shale, seen			4	0
k.	Carbonaceous shale	0	2		
	Coal	1	4		
j.	Brown shale	0	1		
	Grey shale	0	10		
i.	*Coal*	2	2		
	Brown shale...	0	5		
	Coal	0	10		

		Ft. In.	Ft. In.
h.	Brown shale...	0 6	
g.	*Coal*	0 8	
f. {	Grey shale	...	0 2
	Brown shale...	...	0 8
e.	Soft grey sandstone	...	0 2
d.	Brown shale	...	0 3
c.	*Coal*	...	0 4
b.	Carbonaceous shale	...	0 6
a.	Grey shale, seen	...	1 0
	Coal in seam	5 0	
	Carbonaceous shale	0 2	
	Shale	1 10	
	Total thickness of seam...	7 0	

The subordinate layers, it will be seen, vary rapidly in thickness. The top coal (*k*) in the second section is firmer than the corresponding band in the first.

Daohál hill.

Coal was also found by Mr. Greig in a nalla flowing from Daohál hill. When I saw the outcrop, which was only partially cleared, one foot of coal was visible, dipping east-20°-south at 30°. It appears that Major Hannay opened a quarry in 1847 on the north bank of the Dihing,* but no outcrop is now visible. The seam is very likely the same as that which has been worked close to the south bank.

South bank of Dihing.

A quarry in the latter, belonging to the Assam Tea Company, was open in 1865. Mr. Medlicott describes the seam as 17 feet thick, of which about 10 feet seemed good clear coal, but greatly crushed. The dip was very high, and the outcrop about 100 feet above the river.†

* Jour. As. Soc., Bengal, Vol. XVII, pt. I, p. 167.

† Memoirs G. S. I., Vol. IV, p. 400.

This quarry was quite choked up in 1874, but was re-opened experimentally by Mr. Greig. Only part of the seam was visible when I was at Jaipur, the section of which was as follows:—

	Ft.	In.
Coal, seen	1	0
Brown shale	1	2
Grey shale	1	0
Coal	1	0
Brownish-grey shale	0	3
Coal	0	10
Carbonaceous shale	0	7
Coal	2	6
Carbonaceous shale, seen	5	0
Coal, seen	5	4
Carbonaceous shale, seen	5	7
Shale, seen	2	5
	13	4

Dip, east-25°-south at 40°. The coal, as well as the associated shales, contains some pyrites. This is, doubtless, the seam which was worked in 1847 by Major Hannay.

Mr. Medlicott mentions an abandoned quarry, a quarter of a mile south-west of the above, in a different seam.

Path to Hukanjuri.

On the path from Jaipur to Hukanjuri, about two miles south-east of the former place, a seam 9 feet thick is exposed. It had been partly cut through by Mr. Greig in December 1874, exhibiting the following section:—

	Ft.	In.	Ft.	In.
Coal, seen	3	9		
Lenticular layer of brown shale, ½″ to 6″	0	3		
Coal	1	9		
Grey shale	...		8	6
Sandstone, seen	...		6	0
Coal visible in cutting	5	6		
Shale ,, ,, ...	0	3		
	5	9		

Dip, east-35°-south at 65°. Five feet of coal from the surface is sodden; that below, which is separated rather sharply from the sodden

part, is apparently unaltered by the weather. It is, however, crushed, and shows frequent little 'slickenside' faces; it contains pyrites in occasional nodules and more minutely disseminated.

The outcrop of the seam can be traced for 100 yards into adjacent nallas, and some 300 yards to north-north-east there are two or three abandoned quarries, apparently on the same seam. There is said to have also been a quarry about a mile to the south of the Hukanjuri path.

Three miles north of Disang.

In a nalla three miles north of the Disang, the following section is visible :—

	Ft.	In.
Shale and sandstone		
Sandstone dipping E. at 40°	1	6
Coal	1	6
Grey shale	1	3
Carbonaceous shale with *coal*	1	0
Grey shale	5	0
Carbonaceous shale	0	7
Grey shale	23	0
Coal	1	0
Grey shale	20	0
Blank	1	6
Coal, medium hardness; dip E. 15° S. at 50° ...	2	0
Grey shale	10	0
Coal	2	2
Grey shale, seen	2	0

In the Desam nadi, one-third of a mile south of the above, three outcrops are visible, the seams being respectively one, one, and two feet thick.

Nalla north of Disang.

The following outcrops are exposed in a nalla a little north of the Disang :—

	Ft.	In.
1st.—*Coal*	0	10
Brown shale	0	4
Coal	4	6
Carbonaceous shale, seen	1	6

	Ft.	In.
Coal	5	4
Carbonaceous shale, seen	1	6
Shale	0	4
Total visible thickness of seam	7	2

Dip, east-10°-north at 85°; coal of medium hardness.

	Ft. In.	Ft. In.
2nd.—Grey shale, seen	...	2 0
Coal	0 10	
Brown shale	1 6	
Coal, seen	2 8	
Coal visible in seam	3 6	
Shale	1 6	
Total visible thickness of seam	5 0	

Dip, east-20°-south at 80°. This seam is nearly in the same strike as the last and is probably the same.

	Ft.	In.
3rd.—*Coal* (inferior)...	3	0
4th.—*Coal*	1	6
5th.—*Coal* with one or two thin shaly partings; dip E. 20° S. at 50°	3	6
6th.—*Coal*	1	6
7th.—*Coal*	2	6

The 3rd and 4th outcrops may be respectively of the same seams as the 5th and 6th.

Disang River.

In the Disang itself five seams are exposed. The outcrop of the highest of these, which is on the right bank of the river, presents the following section :—

	Ft. In.	Ft. In.
Grey shale, seen	...	1 6
Sandstone	...	0 6
Coal	2 0	
Carbonaceous shale	0 4	

	Ft. In.	Ft. In.
Grey shale	0 4	
Coal	0 2	
Grey shale	0 10	
Coal	0 2	
Brown shale...	0 2	
Grey shale	1 10	
Coal	0 6	
Grey shale	0 7	
Coal	0 7	
Brown shale	0 1	
Coal	0 5	
Brown shale	0 2	
Coal	0 1	
Brown shale	...	0 3
Grey shale, seen	...	1 9
Coal in seam	3 11	
Carbonaceous shale	0 4	
Shale	4 0	
Total thickness of seam	8 3	

Dip, south-40°-east at 70°: coal soft.

On the opposite side of the river, and some 25 yards lower down stream than the line of strike of the last seam, a second is exposed—

	Ft. In.	Ft. In.
Grey shale, seen	...	1 2
Brown shale	...	0 2
Coal	...	0 5
Brown shale	...	0 3
Grey shale	...	0 10
Brown shale	...	0 2
Coal	5 0	
Grey shale, seen	...	3 0
Coal in seam	5 0	

Dip, south-20°-east at 80°: coal soft.

No seams are visible for about 200 yards below this (although such may exist). Then on the same side of the stream about 30 feet above the water we find :—

	Ft. In.	Ft. In.
Fine-grained sandstone, seen		9 0
Coal	5 3	
Carbonaceous shale with layers of *coal*	2 2	
Coal	2 6	
Carbonaceous shale	0 4	
Coal	0 9	
Grey shale, seen	...	2 6
Coal in seam	8 6	
Carbonaceous shale	2 6	
Total thickness of seam	11 0	

Dip, south-15°-east at 60°. The main (5' 3") coal is the best I have seen in the Jaipur field, being of the hard type which is unaltered by exposure to the air;* it contains, however, a few nodules of pyrites. The lower bands are inferior to it, and are water-sodden to a depth of some feet from the surface. This seam has also been quarried on the right bank of the river, where the main coal has about the same thickness as on the left; the lower part of the seam is not visible.

Thirty yards lower down the stream on the same (left) side there is a fourth outcrop—

	Ft. In.	Ft. In.
Grey shale, seen	...	2 0
Coal	13 0	...
Carbonaceous shale with *coal*		1 0
Brown shale		0 6
Gray clunchy shale		1 9
Earthy sandstone		0 9
Grey clunchy shale, seen		1 0
Coal in seam	13 0	

Dip, south-15°-east at 80°. This is the thickest seam visible in the section, but the coal is soft at the outcrop. The old quarry had to be

* p. 78.

cleared out to expose the coal, and has, doubtless, long since been filled up again.

Five yards lower down stream there is a fifth seam, the section of which is as follows:—

	Ft. In.	Ft. In.
Earthy ochreous sandstone, seen	..	1 0
Brown shale	...	0 6
Coal with partings of carbonaceous shale	0 8	
Coal	2 3	
Grey shale	0 5	
Coal	1 10	
Coal with partings of carbonaceous shale	0 7	
Grey shale, seen	...	2 0

	Ft. In.
Coal in seam	4 1
Coal with partings of carbonaceous shale	1 3
Shale	0 5
Total thickness of seam	5 9

Dip, south-15°-east at 60°: coal soft.

Thus there are five known seams in a horizontal distance of about 250 yards, containing the following thicknesses of actual coal:—

	Ft. In.
1st seam (highest)	3 11
2nd "	5 0
3rd "	8 6
4th "	13 0
5th "	4 1
Total ...	34 6

The first is so interbanded with shale that it can scarcely be considered workable, so that the known available thickness of coal in the Disang is about 30 feet. The upper four seams have all been quarried on a small scale; the third and fourth on both sides of the stream.

Boruarchali.

In a nalla south of Boruarchali the following outcrops are visible:—

	Ft.	In.
1st.—*Coal*, seen	1	6
Carbonaceous shale	1	2
Coal	3	2
Coal visible in seam	4	8
Carbonaceous shale	1	2
Total visible thickness of seam	5	10

Dip, east-35°-south at 30°: coal soft.

	Ft.	In.
2nd.—*Coal*, dipping east 40° S. at 50°	2	0
3rd.—*Coal*	1	0
4th.—*Coal* (soft), dipping E. 40° S. at 60°	4	6
5th.—*Coal*	0	8

Gajua Ting.

This coal, to which my attention was directed by Mr. S. E. Peal, of Sapakati, occurs on the northern side of the outlying ridge known as 'Gajua Ting.' In one of the nallas at the base the following section was exposed:—

	Ft.	In.	Ft.	In.
Grey shale, seen			1	3
Coal			0	10
Sandstone			1	6
Blank			3	6
Coal	2	8		
Brown shale	0	6		
Coal	3	5		
Grey shale, seen			1	0
Coal visible in seam	6	1		
Shale	0	6		
Total visible thickness of seam	6	7		

Dip, south-10°-east at 80°: coal of medium hardness. Besides the above, two or three thinner seams were exposed.

Quality of the coal.

Most of the Jaipur coal that I have seen is of the kind that is soft and crumbly at the surface,* and in some of the known outcrops (which seem to be chiefly those near the top of the measures) the value of the coal is depreciated by interbanding with shale. Mr. Medlicott's experience was the same, when coal was being quarried by a native contractor on the bank of the Dihing. He remarks that "all the coal brought to the Brahmaputra for steam purposes is from the Tiráp; the Jaipur coal is used almost exclusively for such purposes as brick and lime-burning."† Other beds, however, are quite free from partings, and some at least, like the 5′-3″ bed in the Disang, are of the first quality as to surface hardness. Captain Hannay also appears to have obtained some hard coal as well as soft in the neighbourhood of Jaipur. "As might have been expected" (he writes), "I did not find the coal of equally good quality throughout, at least with regard to *hardness* and compactness of texture, that which was uppermost being much impregnated with ochrey earth, whilst under this lay the *hardest* and *finest* specimens, the blocks breaking off large, and the fracture exhibiting that beautiful iridescence said to be common in Newcastle slaty coal. Below the last-mentioned description, and as far as I dug down into the vein, *which might have been about 6 feet,* the coal was of a softer nature, intermixed, however, with many lines of hard."‡ If there were any *thick* seams of hard coal above the level of the alluvium, the outcrop would most probably be not altogether concealed, and it is unlikely that the beds would have remained undiscovered during the last forty years, considering the amount of search that has been made in that neighbourhood for coal.

Quantity of available coal.

But it must be remembered that it is only the upper part of the measures that appears above the alluvium level, especially in the northern portion of the field. There is, therefore, every reason to believe that other seams would be

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* p. 79.

† Vol. IV, p. 397.

‡ Jour. As. Soc., Bengal, Vol. VII, p. 953. The italics are in the original.

struck by boring through the alluvium at short distances from the foot of the hills,* and there is no assignable reason why the Jaipur measures should, as a whole, be inferior to those of the other fields, as to either the total thickness or the quality of the contained coal. But the unknown depth of the alluvium leaves it problematical whether coal could be profitably raised from beneath it, this being a point that can only be settled by boring.

The data, then, on which to form an estimate of the total quantity of available coal are insufficient, although it may be safely said that there is a large quantity. The known seams in the northern part of the field include the following thicknesses of coal:—

	Ft.	In.
At Tipám tea garden (4′ 10″ + 4′ 7″)	9	5
„ Dihing river	10	0
„ Hukanjuri path	9	0

but only the very top of the measures is visible. In the nallas half-way between the last locality and the Disang no useful seams were exposed; this, however, cannot be taken as proof of their absence. In the fullest section obtainable—that in the Disang itself—30 feet of workable coal is known to exist; but even here part (and, judging from the thickness exposed in other fields, the greater part) of the measures is obscured. In the imperfect section at Boruarchali 9 feet of available coal is known. The above figures give an average known thickness of 13 feet 6 inches: taking the above considerations into account, therefore, it is certainly not extravagant to estimate the mean available thickness at five yards. As the measures, however, only occur along the skirts of the hills, they seldom or never rise to any considerable elevation above the plain, and the greater portion of the accessible coal is therefore below the alluvium level, and could only be mined towards the deep or by vertical pits. Taking this into account, together with the high dips often met with,

* The testing of such highly inclined measures would, of course, require a larger number of boreholes than would be necessary in strata more nearly horizontal.


Tirap R.
Kher-imGaon
Janglugaon
Leáp
Wallo
Pilingta
Hilika
Semlam
Khongtham
Laktong
Rangkatu

Mallet: *Nágá Hills.*

perhaps not safe to calculate on a band more than 150 yards broad. ording to the above figures, then, we should have between Tipám Boruarchali (a distance of fifteen miles) 15 × 1,760 × 150 × 5 ic yards of available coal *in situ*, containing about 20 million tons, say 10 million tons, of coal in a marketable state. Of course there possibilities, as indicated above, of a much larger supply than this thin these limits. Beyond them, there is the probable extension of e field north-east of Tipám to be considered, and also, perhaps, that uth-west of Boruarchali at a sufficiently small depth below the alluvium vel to admit of the coal being worked.

V.—THE NÁZIRA FIELD.

Limits, &c.

Like the Jaipur, the Názira field is divisible into two sections,—*viz.*, the area drained by the Saffrai and its tributary the Tiru, and that drained by the Dikhu. These basins are separated from each other by a ridge which, at Kongan H. S. and the eminence two miles to the north, has an elevation of more than 2,000 feet; but between these points, at the head of the Tiru, there is a depression or saddle, the lowest part of which is 670 feet above the plains. The same ridge east of Charaido is only a little over 200, and that is probably the route by which it would be found most convenient to transport most of the Saffrai coal. There would, however, if arrangements for transporting coal from the Dikhu valley were organized, be no serious difficulty in utilizing them for the carriage of coal from the upper part of the Tiru also by getting it across the above-mentioned saddle.

As a whole, the coal measures have a high inclination towards the south-east. The northern part of the Saffrai valley being occupied by alluvium, they are seldom visible there except outcropping in the beds of the streams.* The most northerly point at which they have been found is a little below the junction of the Chota Taukák with the main stream. Ascending the latter, the coal rocks are soon replaced by the Disang beds, but south-east of Tirugaon the former again appear, and then a second time, on account of the winding course of the river, give place to the Disang rocks. The coal measures rise above the alluvium in the low hill east of Tirugaon. I regret that I have no observations of them between the end of the Chingan ridge and Chingan hill itself. North-west of the latter, however, they are finely seen in the head-water feeders of the Tiru.

* It is scarcely needful to remark, that the geological lines drawn on the map through the alluvium indicate the probable boundaries of the coal measures beneath it.

The saddle north of Kongan H. S. is covered with surface clay, by which the rocks are obscured, but in the Bor ján and its feeders, in the Dikhu, and various of its lateral nallas, and in the streams below Námsáng, numerous sections are obtainable. The measures here rise to a considerable elevation, seams of coal having been observed on the Naginimora-Kongan path and below Námsáng at altitudes above the plain of 1,700 and 2,000 feet, respectively.

Pieces of coal are washed down the stream which drains the valley between Námsáng and Nángta, but in the Sánga ján the Disang and Tipám groups are in contact.

Probable coal beneath the alluvium to the north of the hills.

Besides the above known coal-field, it is highly probable that the measures occur to the north of the Sub-Himalayan rocks: that is to say, that the Jaipur band is continuous towards the west below the alluvium, and that coal might, therefore, be struck by borings at a certain distance from the foot of the hills west of the Taukák. But the thickness of the alluvium is entirely unknown. Unless the coal were found at a comparatively trifling depth, the advantage of its greater proximity to the Brahmaputra would not outweigh, or even balance, its unfavorable placement, in comparison to the Dikhu valley coal, for mining operations.

Near mouth of Chota Taukák.

Coal outcrops.—In the first nalla after crossing the Saffrai, by the path from Charaido to Lakma, several outcrops are visible. The highest of these has the following section:—

	Ft. In.	Ft. In.
Brown shale, seen	...	0 9
Coal	1 7	
Carbonaceous and brown shale	1 8	
Coal	0 5	
Brown and carbonaceous shale	2 0	
Coal	2 0	
Brown shale	...	0 6

	Ft.	In.
Coal in seam	4	0
Carbonaceous and other shale	3	8
Total thickness of seam...	7	8

Dip south-20°-east at 60°: coal of medium hardness.

A lower seam includes—

	Ft.	In.	Ft.	In.
Brown shale	...		3	0
Coal	3	0		
Carbonaceous shale	0	5		
Coal	2	1		
Pyritous brown shale	...		1	3
Coal in seam	5	1		
Carbonaceous shale	0	5		
Total thickness of seam	5	6		

Dip, east-30°-south at 60°. Hard coal.

In another seam lower down stream, 9 feet of hard coal is exposed, but the total thickness is not visible. Dip, south-35°-east at 80°. Still lower there is another outcrop, very likely of the same seam. Six feet of hard coal are visible, but this is not the entire thickness. Dip, east-10°-south at 60°.

In the Chota Taukák, a little below the junction with the Disang group, one or two thin beds of coal are seen: then, 100 yards from the mouth of the stream, there is a seam of hard coal, only a part (6 feet) of which is exposed; dip, east-30°-south at 50°. Close to the mouth some more coal is exposed.

In the Saffrai, a little above the Chota Taukák, there is a seam which has the following section:—

	Ft.	In.
Coal, seen	2	0
Carbonaceous limestone	0	7
Coal, with a parting of carbonaceous shale ...	0	10
Carbonaceous shale	0	4
Coal, seen	1	0

	Ft.	In.
Coal visible in seam	3	10
Carbonaceous shale	0	4
Limestone	0	7
Thickness of seam visible	4	9

Dip, south-20°-east at 80°: coal hard. The limestone thins out within a couple of yards, being in fact only an elongated nodule.

Fifty yards higher are brown and carbonaceous shales with some thin and crushed layers of coal. Then a 5-feet bed of hard coal dipping east-30°-south at 60°. This seam appears to be the same as the last, and also, perhaps, as the 6-feet seam in the Chota Taukák.

It appears most probable that it was in this part of the Saffrai that Mr. Bruce observed several beds of coal.* Two of them are stated to have been 12 cubits (18 feet) and 25 cubits (37 feet 6 inches) thick, respectively. Nothing of the kind is visible now, but in alluvial ground the river-bed may have shifted considerably in fifty years, and from Mr. Bruce's account, with the illustration he gives,† there seems no reason to doubt the accuracy of his observation. In the figure they are represented as dipping east-30°-south at 60,° one being 100 or 150 feet stratigraphically above the other. The coal is described as superficially inferior to that quarried higher up the river.

Saffrai south-east of Tirugáon.

In the Saffrai south-east of Tirugáon, shales, with thin beds of coal, crop out from beneath the alluvium in two or three places, but nothing of any value is now visible. It was, however, in this neighbourhood, apparently, that Mr. Bruce quarried his coal in 1828. On Thornton's map of the Sibságar district, the survey for which was made in 1839-42, there is "Suffry coal mine" marked on the left bank of the stream here, and although

* Eight, according to his account, but he may have meant *outcrops*, some of which may have been repetitions of the same beds.

† Coal Committee's Report for May 1845, p. 118.

no excavation or seam is now visible, there is a large heap of coal still remaining, from which the site of the quarry is probably not far distant. In Mr. Bruce's illustration it is marked on the left bank of the river. He describes the seam as 24 cubits (36 feet) thick, including a parting of about 4 feet, and the coal in the above-mentioned heap is, even now, of the best quality as to hardness. Some shale beds in the river near it dip east-15°-south at 40°.

Tiru nadi.

Numerous coal seams are to be found in the nallas north-west of Kongan H. S. In the section given at p. 23 there are eight seams in a stratigraphical thickness of 130 feet, and at least a dozen more are visible in the same stream. Most of them are, however, useless, only one of them attaining a thickness of 3 feet.

In another nalla, also, close by, many beds of coal are exposed. The principal outcrops are—

	Ft.	In.
1st.—*Coal*	1	4
Brown shale	0	6
Coal, containing a few calcareous nodules ...	2	4
Coal in seam	3	8
2nd.—Hard *coal*, dipping E. 40° S. at 70°	2	8
3rd.—Hard *coal*, containing a few calcareous nodules: dip W. 40° N. at 80°	7	6

In the stream into which the above nallas flow the following outcrops are visible:—

	Ft.	In.
1st.—Hard *coal*, dipping south 30° E. at 70°	6	0
2nd.—Hard *coal*, containing a few calcareous nodules: dip S. 30° E. at 60°	6	4
3rd.—*Coal* of medium hardness, containing a few calcareous nodules: dip S.-E. at 70°	2	10
4th.—Hard *coal*, dipping E. 20 S. at 60°	4	6
5th.—Hard *coal*, dipping S. at 90°	4	6

The *1st* and *2nd* are very likely outcrops of the same seam.

The majority of the seams in the Tiru are too thin to be of any use, but after making a liberal allowance for this, there still remains a large amount of coal in seams of a convenient thickness for working, and most of which is of the hard kind. I think it is safe to say that there is not less than 15 feet of available coal. The average dip is about 75°.

Bor ján.

At the head of a small nalla on right side of the Bor ján we find—

	Ft. In.	Ft. In.
Thick-bedded sandstone		
Soft *coal*, dipping N-E. at 40°	2 0	
Grey shales and sandstone		
Coal	1 6	
Grey shale		
Rather massive, greyish-white sandstone, seen, about		50 0
Coal (m)*	6 5	
Carbonaceous shale	...	0 2
Grey and brownish-grey shales, seen	...	4 0

Dip of the 6′ 5″ coal north-east at 40°. Coal soft at outcrop. Elevation† 770 feet. This coal has been quarried at one or two points.

In a nalla perhaps 150 yards east of the Apak ján (a nalla joining the Bor ján on right side not far from the boundary of the Sub-Himalayan rocks) there is a seam which includes—

	Ft. In.	Ft. In.
Grey shale, seen	...	1 0
Coal (m)	7 4	
Brownish-grey shale, seen	...	1 3

Dip north-west at 60°. Soft coal. Elevation 460 feet.

On the left bank of the Apak ján there is a very badly seen outcrop—

	Ft. In.	Ft. In.
Coal	3 6?	
Grey shale	1 10	
Coal	2 0	
Grey shale	...	4 0

* The minor seams are not marked on the map, as, on so small a scale, it would only make it confused. Those which are marked are indicated in the text by an (m).

† This, and other elevations subsequently given, are measured from the alluvial plain at the foot of the hills.

Dip, east-30°-south at 70°? Coal soft. Elevation 430 feet. About one hundred yards lower down, within a few yards of the same bank, are two or three old pits from which coal is said to have been formerly raised: if so, it was probably from the continuation of the above seam.

In the bed of the stream, about 10 yards west of the last outcrop, one of a lower seam is exposed—

	Ft. In.	Ft. In.
Grey shale, seen	...	1 6
Coal	...	0 2
Brown shale	...	0 6
Grey shale	...	1 0
Carbonaceous shale	...	0 2
Coal (m)	7 0	
Carbonaceous shale	...	0 6
Grey shale, seen	...	2 0

Dip, east-30°-south at 75°: coal of medium hardness. Elevation 430 feet. The seam can be traced for 25 yards up the bed of the nalla from this point; and in the opposite direction it is exposed at intervals for 80 yards. Where last seen the section is as follows:—

	Ft. In.	Ft. In.
Grey shale, seen	...	3 0
Coal	2 6	
Carbonaceous shale	0 6	
Coal	3 6	
Grey shale, seen	...	1 0
Coal in seam	6 0	
Carbonaceous shale	0 6	
Total thickness of seam	6 6	

Dip, east-40°-south at 85°. The coal is somewhat contorted on a small scale in places, but where not so, it is hard and firm. The elevation here is about 300 feet. This seam is favorably situated for adit-working, as it is nearly vertical and heads straight into the hill-side.

Thus there are four known workable seams in the valley of the Bor ján, containing the following thicknesses of coal:—

		Ft.	In.
1st	... ...	6	5
2nd	... ...	7	4
3rd	... ...	5	6?
4th	... ...	6	6
	Total, about	25	9

Wákang ján.

In the right branch of the Wákang nadi the following section is exposed:—

	Ft.	In.	Ft.	In.
Grey shale, seen	...		3	0
Coal	1	7		
Grey shale	2	6		
Coal	0	7		
Carbonaceous shale with layers of *coal* ...	2	7		
Coal	1	4		
Brown shale	4	0		
Coal	1	0		
Brown shale, with some carbonaceous layers, seen	...		15	0
Coal in seam	4	6		
Carbonaceous shale	2	7		
Shale	6	6		
Total thickness of seam ...	13	7		

Dip, north-20°-west at about 60°, but the beds are contorted considerably. Fifty yards lower down stream we find—

	Ft.	In.	Ft.	In.
Impure limestone	...		0	9
Grey and brown shale	...		12	6
Coal (m)	12	9		
Carbonaceous and grey shale	4	0?		
Coal (m)	12	4		
Grey and brownish-grey shale	...		13	0
Coal and carbonaceous shale	...		1	4
Grey shale	...		3	6
Coal	...		2	0
Grey shale, seen	...		8	0
Coal in main seam	25	1		
Carbonaceous shale, &c.	4	0?		
Total thickness of seam, about ...	29	1		

Dip, south-40°-east at 80°. The lower band of the main seam is of the best hard coal; the upper is of medium hardness. Lower down stream beds of 2′ 0″ and 1′ 6″ are exposed. The 29-feet seam is, perhaps, 300 yards above the junction of the two branches of the Wákang, and at an elevation of 670 feet above the plain.

Some half mile or so above the junction, in the left (southern) branch, there is a section exposed as follows:—

	Ft. In.	Ft. In.
Grey and brownish shales, with some arenaceous layers near the bottom		9 0
Pyritous carbonaceous shale		0 2
Coal (m)	7 6	
Brown shale		0 3
Grey shale		2 6
Brown shale		1 6
Grey shale		4 2
Coal		2 0
Brownish-grey shale, with a few strangulated layers of impure limestone		8 6
Blank, perhaps		20 0
Coal		0 8
Clunchy and brown shales, perhaps		30 0
Coal		1 3
Coal in main seam	7 6	

Dip of main seam east-10°-south at about 30°. The coal is of the best hard kind. Elevation 940 feet. Lower down stream three or four seams are exposed, but none of them are workable. There is also one obscured by a landslip, amongst the debris of which are lumps of good coal.

Where the path from Naginimora to Kongan crosses a nalla west of the village, an inferior seam of coal is visible at an elevation of 1,700 feet.

Kongan path

In a small stream joining the Dikhu near the boundary of the Tipám rocks, two or three seams are visible; none of them, however, are of workable thickness.

Neighbourhood of Tel Pung. East of Dikhu.

On the right-bank of the Dikhu, about 500 yards above Tel Pung, there is a seam of coal which was being quarried last cold weather for the Assam Tea Company. The section is given at page 25, the dip being east-20°-south at 65.° Two hundred yards north of this point the seam crops out again, dipping east at 25°. Here, owing to its striking obliquely to the slope of the hill, it is 230 feet above the Dikhu. One hundred yards further north, on the Kongan-Námsáng path, it is also exposed, and again, less completely, in a stream 30 yards beyond. Here the dip is east-20°-south at 25°; elevation above Tel Pung 230 feet, or say 350 feet above the plains. The seam was formerly quarried close to the path. The coal is of the hard kind, and averages about four feet in thickness (m).

In the above-mentioned stream there are two or three other outcrops (*vide* section, p. 21), and several on the Kongan path above Tel Pung, but none of these are of any importance. There is also a worthless seam in the Dikhu itself close to the oil-spring.

In the first nalla below Tel Pung we find :—

	Ft. In.	Ft. In.
Brown and grey shale	...	4 0
Coal	1 8	
Brown shale	0 3	
Coal	0 4	
Grey shale	...	2 0
Coal in seam	2 0	
Shale	0 3	
Total thickness of seam ...	2 3	

Dip, west-30°-north at 80°. A little lower down stream there is seen—

	Ft. In.	Ft. In.
Grey shale	...	4 0
Coal	0 3	
Brown shale	0 9	
Coal	0 3	
Coal interbanded with carbonaceous shale ...	0 6	
Coal	0 11	
Grey shale	...	1 0

	Ft.	In.
Coal in seam	1	5
Coal with carbonaceous shale	0	6
Shale	0	9
Total thickness of seam ...	2	8

Dip, west-10°-north at 60°. A couple of hundred yards lower down we have:—

	Ft.	In.	Ft.	In.
Grey shale	...		6	0
Coal	2	8		
Grey shale with 1 or 2 thin layers of *coal* ...	...		4	6
Coal	...		0	2
Brownish-grey shale	...		1	0
Coal	...		0	9
Carbonaceous shale	...		1	8
Grey shale	...		1	6
Thickness of main coal ...	2	8		

Dip, east-10°-south at 50°. Coal soft.

Neighbourhood of Tel Pung. West of Dikhu.

In the Hil ján, a small stream which joins the Dikhu above Tel Pung, there is a seam visible which has the following section:—

	Ft.	In.	Ft.	In.
Brownish-grey shale, seen	...		2	0
Coal (m)	2	11		
Brownish-grey shale, seen	...		2	0

Dip, south at 50°. Coal of medium hardness.

A few yards lower down we find:—

	Ft.	In.	Ft.	In.
Grey shale, seen	...		3	0
Carbonaceous shale with layers of *coal*	...		1	4
Coal	2	0		
Carbonaceous shale	0	4		
Coal	0	6		
Sandstone...	...		0	8
Coal	...		0	1
Brown shale	...		0	6
Coal	...		0	3

	Ft. In.	Ft In.
Carbonaceous shale	...	0 9
Grey shale, seen	...	2 0
Coal in main seam	2 6	
Carbonaceous shale	0 4	
Total thickness of seam ...	2 10	

Dip, about east-30°-south at 30°. Coal soft. One hundred and fifty yards lower there is a third outcrop :—

	Ft. In.	Ft. In.
Brownish-grey shale, seen		1 6
Coal	0 4	
Brown shale	0 3	
Carbonaceous shale	0 4	
Coal	0 5	
Brown shale	0 5	
Carbonaceous shale	0 5	
Coal	0 8	
Carbonaceous shale	...	0 9
Coal	...	0 1
Grey shale, seen	...	2 6
Coal in seam	1 5	
Carbonaceous shale	0 9	
Shale	0 8	
Total thickness of seam ...	2 10	

Dip, south-east at 60°. Two or three other seams of insignificant thickness are also visible in this nalla.

Rather high up in the first lateral stream below Tel Pung we find :—

	Ft. In.	Ft. In.
Grey pyritous shale, seen	...	0 3
Coal	1 5	
Carbonaceous shale	1 9	
Coal	1 1	
Brownish-grey, slightly pyritous shale	...	2 0
Coal in seam	2 6	
Carbonaceous shale	1 9	
Total thickness of seam ...	4 3	

Dip, south-20°-west at 15° ? Coal soft. Elevation about 750 feet.

In the second nalla below Tel Pung, at an elevation of about 500 feet, there is a seam exposed which is much crushed at the outcrop, so that the thickness is not clear. There appears to be a total quantity of about 3′ 6″ of coal divided by a band of shale; lower down there is another crushed seam about 2′ 6″ thick, and one or two still thinner. In a watercourse, 150 yards east of this nalla, an inferior seam is exposed dipping south-30°-east at 60°.

Close to the Námlen ján below Námsáng, there is a seam exposed with the following outcrop :—

Below Námsáng.

	Ft.	In.	Ft.	In.
Brownish shale			0	9
Carbonaceous shale			0	6
Brownish shale			2	0
Coal	5	6		
Brown shale, seen			0	8

Dip, east-30°-south at about 30°. Coal soft. Elevation 930 feet. A few yards lower are the seams of which the section is given at p. 26, *viz.* (*i* to *e*), including about 6 feet of coal of medium hardness, dipping east-20°-south at 60° (m.), and (*c* and *b*) containing 8 feet of inferior coal: (*c*) may be the same as the 5′ 6″ coal in the above section, dropped down by a slight fault.

About 100 feet lower there is a 4-feet seam of coal (m) of medium hardness, dipping east-30°-south at about 30°.

The Námlen ján falls into the Apcha ján. A little below the mouth of the former a 2-feet bed is exposed, and a short distance to the right of the stream there is an outcrop of which the following is the section :—

	Ft.	In.	Ft.	In.
Brown shale, seen			1	9
Coal	3	4		
Brown shale			0	9
Brownish-grey shale, seen			2	3

Dip, about south-30°-east at 40°. Coal of medium hardness.

On the Námsáng-Giliki path, a little below the village, there is a thin seam at an elevation of 2,000 feet above the plains.

The bed examined by Mr. Thornton in 1848 is situated in this neighbourhood at an elevation of 1,400 feet. He describes it as 10 feet thick, including 3 to 4 feet of good coal, dipping at about 35°.

The principal known seams, then, below Námsáng contain the following thicknesses of coal:—

			Ft.	In.
Near Námlen ján	...	No. 1	5	6
		„ 2	6	0
		„ 3	8	0
		„ 4	4	0
Near Apcha ján	...	„ 5	3	4
Mr. Thornton's seam	...	„ 6	3	6

No. 1 and the upper part of No. 3, being perhaps the same bed, and inferior in quality, may be excluded from the list of available seams, leaving four workable ones containing about 17 feet of coal.

Quantity of available coal.
Saffrai.

As in the cases of the other fields, the data are insufficient for forming an estimate of the total quantity of available coal, although they will serve to show that a large quantity may be depended on. In the Saffrai, the measures are known to extend from north of the Chota Taukák to south-south-east of Tirugáon, a distance of about 4½ miles. In the northern part of this area the known workable seams are respectively 4′ 0″, 5′ 1″, 9′ 0″, 18′ 0″, and 37′ 6″ thick, containing a total of 73 feet 7 inches. South of this the ground is obscured by alluvium, and in the southern part of the area only one workable seam is known, which contains 32 feet of coal. The mean of these numbers gives an average of about 17 yards. As the coal is altogether below the alluvium level, 150 yards (equal to a vertical depth of about 350 feet with a dip of 50°) is perhaps as great a depth as can be safely taken to be within practical reach.

These figures, then, indicate an available band measuring $4\frac{1}{2} \times 1{,}760 \times 150 \times 17$ cubic yards, containing about 20 million tons of available coal in site, or say 10 million tons of marketable coal.

Tiru and Dikhu.

As the easiest means of transport for the coal at the head of the Tiru would probably be *viâ* the Dikhu valley, it should be grouped with the coal in the latter rather than with that in the Saffrai. The following thicknesses of coal are known to exist:—

	Ft.	In.
In Tiru	15	0
„ Bor ján	25	9
„ Wákang ján	32	7
Vicinity of Dikhu	4	0
Below Námsáng	16	10
Average	18	10

or about 6 yards. As the measures are considerably elevated above the plains, and adit workings could not unfrequently be resorted to, the coal for a breadth of 200 yards may be considered as profitably within reach. The distance from the Tiru to north-west of Námsáng being seven miles, we have, according to these figures, an available band containing $7 \times 1{,}760 \times 200 \times 6$ cubic yards, or nearly 15 million tons of coal *in situ*, equivalent to say half that amount of marketable coal.

In the above estimate no account has been taken of the possible extension of the field, at a workable depth below the alluvium, north of the Chota Taukák, nor of the Chingan ridge, where the coal measures have not been actually proved to exist, nor of the portion of the field north of Nángta, where, although coal is known to occur, no workable seams are on record.

VI.—THE JÁNJI FIELD.

This is a small and comparatively unimportant field. The measures occur as a narrow strip along the course of the Jánji, and its tributary the Sánga ján, for a length of, perhaps, a couple of miles. The strata throughout are almost vertical, generally dipping about south-30°-east at a very high angle.

Coal outcrops.

In the Sánga ján, some 300 yards above its mouth, one or two thin beds of coal are visible.

A little way up one of the lateral streams falling into the Jánji, Mr. Wallace of Amguri observed a seam which he describes as being two feet thick and vertical.

On the right bank of the Jánji, about three-fourths of a mile above the Sánga ján, a seam is exposed which has the following section:—

	Ft. In.	Ft. In.
Grey shale, seen	...	0 9
Coal (inferior)	1 0	
Coal (hard)	2 0	
Carbonaceous shale	...	0 4
Brown shale, seen	...	1 0
Coal in seam	3 0	

Dip, south-30°-east at 80°.

VII.—The Disai Field.

My examination of the Disai field is very incomplete, having been made before any maps of the ground were available.

The coal measures occur in the neighbourhood of Jápu, near the base of the ridge on which the village is situated, and also in the bed of the Disai itself. They are flanked on both sides by Sub-Himalayan rocks, which overlie them on the south and are faulted against them to the north. There is a considerable amount of irregular disturbance by which the strata are inclined at various angles and in different directions: the prevailing dip is about south-30°-east.

The eastern extension of the field is uncertain. Most probably the fault along the northern boundary is continuous with the main fault in the Dikhu and Jánji, in which case it is not unlikely that the measures might be found at the head of the Tiru nadi. But somewhere east of the Disai they are cut off, as the Disang and Tipám groups are in contact in the Jánji. How far the coal rocks extend to the west up the Disai valley is unknown, but the comparatively few pieces of coal to be seen in the river near Jápu, and their small size, would not lead one to expect a very great development of the measures higher up stream.

Coal outcrops.

About half a mile from the Disai, up a small lateral stream north-30°-west (?) of Jápu, five or six seams, associated with grey shales and sandstone, are visible within a distance of about 30 yards. One is 4 feet thick, another 3, and others vary from 6 to 18 inches. The dip is about east-30°-north at 60°, but is irregular. The coal is soft and much crushed.

On the left bank of the Disai west (?) of Jápu a seam outcrops, which presents the following section:—

	Ft. In.	Ft. In
Sandstone, seen	...	10 0
Coal	3 0	
Carbonaceous shale	...	0 4
Grey shale, seen	...	6 0

Dip, south-west at 30°. Coal soft and crushed.

In a lateral stream, joining the Disai a couple of miles higher up, a thinner seam is visible, of which the section is as follows:—

	Ft. In.	Ft. In.
Grey shale, seen	...	0 6
Coal	1 4	
Brown shale	...	0 5
Greyish white shale, seen	...	1 6

Irregular dip to south-east at about 20°. Coal soft and crushed.

VIII.—Economic Geology.

Coal.

External characters. Hard coal.

In the preceding pages it is indicated, as a rule, whether the coal, at the outcrop, is 'hard' or 'soft'. The distinction is an important one with reference to the market value of the fuel. The best hard coal is very homogeneous in structure, with little or no 'cleat,' and without apparent lamination planes. So capable is it of withstanding the weather, that sometimes a seam of this variety forms a cliff on the hill-side, or obstruction in a river bed, from which the associated shale and sandstone have more or less weathered away. It is fresh and unweathered on faces that have been exposed for ages. No difference is apparent between a piece broken from the surface and one taken from the interior. It can be quarried in large blocks, which are firm and hard, and which can be stored for an indefinite time without injury. Thus, in the Saffrai valley, near the site of the 'coal mine' marked on Thornton's map (1839-42), there is an old moss-covered heap containing several tons of coal in blocks averaging perhaps a cubic foot in bulk. The natives say it has been there years and years, but none can say how long. One middle-aged man told me that, when a boy, he had once gone to the place fishing, and had found the heap just as it is at present, covered with moss and ferns. There is a tradition that a European left the coal there, and I think there can be little doubt that it is some of that raised by Mr. Bruce in 1828. Yet, after nearly 50 years' exposure to the weather, the lumps are as hard as if newly taken from the quarry: the fracture is rather duller, or less lustrous, than that of freshly-hewn coal, but that is all the difference discernible.

Sometimes the hard coals display on the broken face a rather small cuboidal fracture, the sides of the cuboids being parallel and perpendicular to the plane of bedding. This variety is somewhat more tender

than that in which no regular structure is apparent. There is a gradation from the hard to the soft coals, no hard line existing between them.

Soft coal.

The soft coals are very tender at the outcrop. For some distance—a few inches or feet—from the surface, they are weathered and sodden. The portion immediately below, which is often separated rather sharply from the sodden part, is very tender, so that most of it crumbles into slack or small coal, and what remains in lumps is too fragile to bear rough usage. But there is reason to believe that this part also has been acted on by the weather, and that many, at least, of such coals are compact enough at a few yards from the surface when freshly exposed. The main causes to which the brittleness of these coals is due seem to be, (1) lamination, giving the coal a tendency to exfoliate; (2) jointing on a small scale, which sometimes divides it into small pieces; (3) the presence of minutely disseminated pyrites, the sulphates, resulting from the oxidation of which, in crystallizing cause the coal to exfoliate and to split along the joints, and sometimes (4) crushing of the coal from pressure. The unalterable character of the hard coal appears to be mainly due to the absence of these conditions. But it remains to be seen whether the same seam retains its character throughout in this respect. Between two and three hundred yards from the Dikhu there is an outcrop of the 4′ Tel Pung seam (p. 25), at which the coal must have been exposed for years without deterioration. In the same seam a quarry was worked last cold weather near the bank of the Dikhu 30 feet above the water. A sample of coal about a cubic foot in size, which was hard and sound at the time, was taken in December and carefully packed away. Five months later it was found to have broken up into small pieces, which were studded with minute crystals of copperas. The amount of pyrites in this coal was not large, the total quantity of ash being only 3·2 per cent.

Sometimes part of a seam, measured vertically, is hard and the rest soft, like No. 3 in the Disang, but more commonly the seam has much the same character throughout.

Composition.

The following assays have been made of Upper Assam coals.

No. of Assay.	Seam—Locality.	Character of coal at outcrop.	Fixed Carbon.	Volatile matter (exclusive of water).	Hygroscopic water.	Ash.	Caking properties.	Color of Ash.
	MAKUM FIELD.							
1	9 feet band, Tiráp quarries ...	Hard ...	60·7	34·8	2·2	2·3	Cakes strongly.	Red.
2	Seam S. E. of Leáp, average ...	Ditto ...	54·2	34·6	3·4	7·8	Ditto ...	Do.
3	6 feet band, N. E. of Tikák ...	Medium	61·2	36·2	*	2·6	Ditto ...	Do.
4	13 feet band, W. of Tikák ...	Ditto ...	66·1	33·5	*	·4	Ditto ...	Do.
5	11 feet 9 inches band, Rángring ...	Ditto ...	65·5	33·2	*	1·3	Ditto ...	Do.
6	4 feet seam, Rángring ...	Hard ...	57·0	37·8	*	5·2	Ditto ...	Do.
7	106 feet seam, Námdáng ...	Ditto ...	58·9	33·6	2·0	5·5	Ditto ...	Greyish white.
	JAIPUR FIELD.							
8	8 feet seam, Tipám	Soft ...	52·8	31·8	7·2	8·2	Does not cake	Red.
9	6 feet 11 inches seam, Tipám ...	Ditto ...	47·5	36·2	5·6	10·7	Ditto ...	Reddish.
10	2 feet 6 inches band, S. bank of Dihing.	Ditto ...	56·2	35·4	6·2	2·2	Cakes very slightly.	Red.
11	9 feet seam, Hukanjuri path ...	Ditto ...	57·4	33·4	5·2	4·0	Ditto ...	Do.
12	2nd (5 feet) seam, Disang River ...	Ditto ...	55·8	33·3	8·5	2·4	Does not cake	Do.
13	5 feet 3 inches band, 3rd seam, ditto	Hard ...	55·4	38·3	4·1	2·2	Cakes ...	Do.
14	4th (13 feet) seam, ditto ...	Soft ...	58·4	35·2	5·2	1·2	Cakes slightly	Do.
15	5th (5 feet 9 inches) seam, ditto ...	Ditto ...	56·4	34·3	5·4	3·9	Does not cake	Light-red.
	NA'ZIRA FIELD.							
16	5 feet seam, Saffrai River ...	Hard ...	56·1	33·9	6·8	3·2	Cakes ...	Red.
17	Coal from Mr. Bruce's heap ...	Ditto ...	56·9	32·0	10·4	·7	Does not cake	Reddish white.
18	6 feet 4 inches seam, Tiru nadi ...	Ditto ...	56·8	33·4	7·8	2·0	Ditto ...	White.
19	6 feet 5 inches seam, Bor ján ...	Soft ...	54·0	37·6	4·4	4·0	Ditto ...	Reddish white.
20	7 feet seam, Bor ján ...	Medium	51·5	40·3	3·4	4·8	Cakes very slightly.	
21	7 feet 6 inches seam, Wákang ján ...	Hard ...	58·0	37·0	2·8	2·2	Cakes strongly	Red.
22	12 feet 9 inches band, 29 feet seam, Wákang ján.	Medium	59·2	34·3	4·1	2·4	Ditto ...	Do.
23	12 feet 4 inches band, 20 feet seam, Wákang ján.	Hard ...	58·2	34·4	4·4	3·0	Ditto ...	Do.
24	4 feet seam, Tel Pung, outcrop A	Ditto ...	61·6	31·2	4·0	3·2	Ditto ...	Do.
25	4 feet seam, Tel Pung, outcrop B ...	Ditto ...	64·9	30·2	4·2	·7	Ditto ...	Do.
26	4 feet seam, Námlen ján ...	Medium	58·7	30·9	8·5	1·9	Does not cake	Do.
	JA'NJI FIELD.							
27	2 feet band, 3 feet seam, Jánji River	Hard ...	52·9	33·8	6·8	6·5	Does not cake	Red.
	DISAI FIELD.							
28	4 feet seam, Disai Valley ...	Soft ...	54·9	36·9	3·4	4·8	Cakes slightly	Red.

* These four coals were assayed after the expulsion of moisture.

The above figures show that the differences observable between the various coals as to hardness cannot be ascribed to any essential difference in general composition. The table may be summarised thus*—

	Average Composition.			
	Fixed carbon.	Volatile matter.	Hygroscopic water.	Ash.
11 Hard coals	58·0	34·1	4·4	3·5
3 Medium „	56·5	35·2	5·3	3·0
9 Soft „	54·8	34·9	5·7	4·6
Average of 23 coals ...	56·5	34·6	5·0	3·9

or exclusive of hygroscopic water—

	Fixed carbon.	Volatile matter.	Ash.
12 Hard coals	60·3	35·9	3·8
6 Medium „	62·0	35·7	2·3
9 Soft „	58·1	37·0	4·9
Average of 27 coals ..	60·0	36·2	3·8

It is probable that in many cases the coals which are soft and crumbly at the outcrop would, *when freshly raised* from a comparatively trifling depth below the surface, be found as serviceable as the hard. But there is reason to fear that the soft coals would deteriorate more or less rapidly by keeping, and that it would be necessary to arrange for their consumption without much delay. The best hard coals, on the contrary, could be stacked for an unlimited time without injury.

Sulphur.

The amount of pyrites in the Assam coals varies considerably. Few, if any, of them are free from it, but its injurious effect in disintegrating the coal depends to some extent on its mode of occurrence. When segregated into nodules, its action is less, both chemically and mechanically, than when more minutely disseminated. In some coals the amount is objectionably large, and to

* No. 17 is not included in this summary.

it may, perhaps, be ascribed the complaints that one occasionally hears from engineers who have tried the coal of its 'burning the fire-bars.' But in the best coals, like Nos. 4, 17 and 18, the quantity is trifling.

As the assays were necessarily made on samples that had been collected some time previously, the percentage of hygroscopic water is probably lower than would be generally found in freshly-raised coal.

Caking properties.

Nearly all the hard coals caked strongly in the crucible, yielding a firm, but sometimes tumid, coke. The soft coals caked slightly, or not at all. But it is known that some coals lose the property of caking after they have been exposed to the air for a time, and it is quite possible that some, at least, of those in question would be found to cake when freshly raised. The coal from Mr. Bruce's heap is one of the few non-caking hard coals, and it has most probably lost the property from exposure. The caking character of the Assam coal is a most important advantage, in rendering the utilization of the slack from the mines feasible, by its conversion into coke; and for steam purposes, a mixture of coal and coke may be found preferable to the former used alone.

Comparison with Ráni-ganj coal.

Compared with Rániganj coal, which is now supplied to the Brahmaputra steamers, good Assam coal differs in outward appearance by the absence of the markedly laminated structure seen in the former. The Rániganj coal is "invariably composed of laminæ of varying thickness, and consisting alternately of a bright jetty black substance, and of a dull lustreless rock. * * * On a close examination, the brighter streaks are seen to have a lenticular section. Where thickest, they seldom exceed an inch, and they thin out towards both ends. They appear to be flattened masses of irregular shape in a matrix of a dull black color."* The better Assam coal, on the other hand, is very homogeneous, and frequently so devoid of visible

* Vol. III, p. 139.

lamination, that it is difficult to find any traces of bedding in hand specimens. The color of the streak or powder is a lighter brown than that of the Ránigani coal.

A list of assays of 17 Ráníganj coals may be found in Vol. III, page 189, which compares thus with the assays of Assam coals given above :—

	Fixed carbon.	Volatile matter.	Ash.
Average composition of 27 Assam coals ...	60·0	36·2	3·8
Ditto of 17 Ránígani coals ...	51·1	32·6	16·3

The Assam coals contain, on an average, more carbon than the Ráníganj, and only one-fourth the amount of ash. As samples of the best class of coal from each field, we may take the following :—

	Fixed carbon.	Volatile matter.	Ash.
4′ seam, Tel Pung, Dikhu valley (⅞) ...	66·0	32·0	2·0
Sánktoria seam, Ráníganj	63·3	27·5	9·2

Quarrying and mining.

The coal has hitherto been worked merely by surface scratchings that can hardly be dignified by the name of quarries, and necessarily the amount raised has been quite insignificant. With few exceptions, the seams are most unfavorably placed for open workings. Dipping, as they generally do, at high angles in the opposite direction to the slope of the hill, it is easy to see that, at a very small distance from the outcrop, the 'overburden,' or superincumbent soil and rock, must attain a thickness too great to allow of the quarry being carried further. Thus, the slope of the hill being 30° and the dip of the coal 30° also (a lower dip than is very commonly met with), the depth of overburden will equal the distance from the outcrop measured parallel to the dip of the bed. In quarrying such a seam, 10 feet thick, at no greater distance than 10 yards from the outcrop, the depth of overburden will amount to treble the thickness of the coal. With higher dips the difficulty becomes still greater. Hence the invariable fate of such quarries, in seams of moderate thickness, is either collapse from undercutting the coal, or voluntary

abandonment after a trifling quantity has been extracted. In the Makum field the great thickness of coal at some outcrops, and the circumstances of its position, as well as the comparatively low dips sometimes met with, offer greater facilities for quarrying than are, I think, to be met with elsewhere. But, even there, the total quantity that could be obtained by such means is quite trifling compared to that within reach by mining.

With reference to mining operations, the coal may be divided into that below the level of the plains and that occurring in the hills above the same level. The former must be worked by shafts or steep inclines, and power provided both for draining the mines and raising the coal, while the latter can, in many cases at least, be got at by adit workings, which would drain themselves, and through which the coal could be run out along the level. To the former division belongs most of the coal in the Jaipur field and in the Saffrai; to the latter a large proportion of the coal in the Makum field and still more of that in the Dikhu valley.

In both positions, the high, and sometimes rapidly varying, inclinations of the seams will render necessary a system of mining different from that pursued in existing Indian coal mines. The quantity of petroleum, accompanied by marsh gas, connected with the Assam coal, is suggestive that fire-damp is another difficulty that will have to be contended with. Skilful superintendence, therefore, will be a necessary condition involved in the successful opening out of the coal-fields.

Relative advantages of the different fields.
Makum.

From the foregoing observations it will be seen that in the Makum field there is a large quantity of coal above the level of the plains, and that, although the coal is not very favorably placed for open workings, there are greater facilities for such in that area than in the fields to the west. The seams are within 2 to 4 miles of the Dihing, the construction of a road to which would involve no difficulty. But the point of shipment is 25 to 32 miles higher up stream than the Jaipur measures, and where the river cuts through the Tipám range there are several

rapids. None of these, however, are of a dangerous character, nor would they present any great difficulty to regular navigation.* The distance by land from the Makum field to the river at Dibrugarh, by the route considered most advisable by the Government of Assam, is about 63 miles.

Jaipur.

In the neighbourhood of Jaipur it is only a small part of the measures that appear above the alluvium level, and nearly all the coal yet found is of the kind that is crumbly at the outcrop. But as the measures cross the Dihing, the coal could be raised close to the river bank, and the distance down-stream to the Brahmaputra is only 82 miles; the Dihing being the largest and most navigable stream between Dibrugarh and Jorhát. The Jaipur coal also has the advantage of being situated below the rapids. The distance to the Brahmaputra, along the line of the present road, is about 40 miles.

Disang.

In the neighbourhood of the Disang, the measures are somewhat more fully exposed, although the greater part of them are below the alluvium level. Some of the coal is of the best quality and the measures cross the river. But as far as Kumár's ghát, 8 miles below the coal, there are numerous rapids, and the river is practically unnavigable in the dry season,† so that it would

* For more than 20 miles below the mouth of the Tiráp, the river has the same character as below Jaipur, namely, a wide sandy channel with steep alluvial banks; and the quantity of water is nearly the same, the only affluent of any importance being the Námsáng. Then the river enters the gorge of the Tipám range, and for 11 miles flows between very low jungle-clad hills. In this part of its course, between reaches of deep water, there are several rapids, but none of them are bad ones, nor is the current unmanageably swift. The water flows over coarse shingle, and the channel is free from rocks. On the 25th of December, when the river is almost at its lowest, Mr. Goad and I descended the stream from Makum to Jaipur, and found a minimum depth of 2 feet in the central part of the rapids, which is as much as can always be depended on in the sandy parts of the river above and below the gorge. At the latter end of March I found between Námsáng and Jaipur a minimum depth of 3 feet.

† On the 1st of January I went down about half-way in a dug-out of the smallest size. At several of the rapids the boatmen were obliged to get out and help the almost empty boat over the shingle.

be necessary to transport the coal by land for a distance of about 4 miles. From Kumár's ghát to Disang Mukh is 100 miles, the river being considerably smaller and less easily navigable than the Dihing. The distance by land to the Brahmaputra is about the same as from Jaipur.

Saffrai.

In the Saffrai all the known coal is below the alluvium level.* South of the Dhodar Alli, the stream is quite unnavigable in the dry season from want of water, and almost equally so in the rains on account of the violence of the current.† The distance by land from the mouth of the Chota Taukák to Disang Mukh, *viá* Charaido and Názira, is about 30 miles, with a low range of hills to cross west of the Tiru.‡

Dikhu.

A large proportion of the available coal in the Dikhu valley is above the level of the plains, or the river bed. As far as Santak, however, there are continual rapids in the Dikhu, and for the steady transport of any considerable quantity of coal, the stream may be considered unnavigable.§ Any scheme, therefore, for conveying the coal to the Brahmaputra by water would almost necessarily involve the construction of a road from the mines to Santak, a distance of 7 or 8 miles. Below Santak the river is navigable for the largest-sized boats in the rains, but in the cold weather it is impassable for those drawing much over a foot of water. The distance

* The quantity in the hill east of Tirugaon, above the water level, is very trifling.

† p. 4.

‡ The highest point of the present path from Charaido to the Saffrai valley is 220 feet above the plains, but it is quite possible that a lower route than this could be found.

§ Less than a mile above Tel Pung the Dikhu flows through a narrow rocky gorge encumbered with fallen masses of rock, the stream being quite impracticable for even the smallest dug-outs. From the lower end of the gorge to Santak, the course of the river includes short reaches of quiet water connected by rapids, the fall of some of which amounts to several feet. The exact number between Tel Pung and Santak, a distance of about 15 miles, is said to be 48, or one every third of a mile on an average. This part of the river is navigable, even in the dry season, for dug-outs lightly laden—Mr. Thornton states that canoes of 15 or 20 *mans* burden can ascend at that time, and of 100 *mans* in the rains—but for the steady transport of any large quantity of coal, it must, I think, be considered impracticable.

from Santak to the Mukh by river is 47 miles. By land, the distance from the coal-field to Disang Mukh is 30 miles.

Jánji.

The Jánji field is a small and comparatively unimportant one, and the coal is at the bottom of the valley. For some miles below it, the river flows through a rocky gorge, where the stream is quite impracticable, and below that for a considerable distance there are numerous rapids. The distance by land to Amguri, where the navigation may be said to commence, is about 10 miles, and thence by water to the Mukh 35. By land from the coal to the Brahmaputra is 28 miles.

Disai.

The Disai coal, as far as known, is of the soft crumbly kind, and is near the base of the hills. The river is quite useless for navigation, except, perhaps, in the rains. From the coal-field to the Brahmaputra by land is about 26 miles.

If, then, an attempt should be made to utilize existing water communications for the transport of the Assam coal to the Brahmaputra, it appears to me that the Makum field offers the greatest number of advantages. There are greater facilities for level workings there than in any of the other fields, except the Dikhu valley, and some of the Makum coal is more favorably placed for open workings than any I have seen elsewhere—an important advantage if the out-turn were confined to a small amount, such as could not be economically raised from regular mines under skilled superintendence. With the exception of the beds at Jaipur, the seams are closer to navigable water than those anywhere else. And, although the Makum field is furthest of all from the Brahmaputra, the Dihing is superior to any of the other streams in respect to navigability.

But if artificial means of communication should be provided, whether by road, or tramway, or canal*, the lie of the coal with reference to mining and its nearness to the Brahmaputra, point to that in the Dikhu valley as being the most favorably situated.

* The construction of a canal is, I think, well worthy of consideration, on account of the almost perfect flatness of the alluvial plains between the foot of the hills and the Brahmaputra, and the abundant water-supply for such obtainable from the hills.

Petroleum.

The intimate connection of the Assam petroleum with the coal measures is too obvious to escape attention. Altogether, the oil is known to rise in contiderably more than a dozen localities, every one of which is either on, or close to, the outcrop of the coal-bearing group. With the exception of the Jánji, petroleum has been found in every coal-field from the Námrup to the Disai, and there is no recorded instance, that I am aware of, of its occurrence elsewhere in Upper Assam. In the majority of cases the springs are near the outcrop of one or more seams of coal, and in one instance I have seen the oil oozing out of the coal itself. This, however, may possibly have been accidental, the coal being merely the last rock through which the oil passed on its way to the surface. But, on the other hand, there is reason to believe that a very moderate heat, such as would be afforded by the natural temperature of the ground near the surface and the chemical action involved in the process, is sufficient for the production of petroleum under certain conditions.

Marsh gas is a frequent accompaniment of the oil, and there may also be a connection between the latter and the saline springs which were formerly utilized by the Assamese for the production of salt, at Borhát, Jaipur and elsewhere. The association of petroleum and salt or saline springs is very common. In India it has been observed both in Burmah* and the Punjab,† although Mr. Theobald is of opinion that the co-existence of the two in the former province is merely fortuitous.

It was clearly shown by the results of Mr. Goodenough's attempt to bring the petroleum into the market ‡ that the supply is abundant near Makum; and it is not unreasonable to hope that it will be found equally large further west. In the Dikhu valley the conditions most

* Records, Geological Survey of India, Vol. VI, p. 70.

† Memoirs, Geological Survey of India, Vol. XI, pt. 2, p. 25.

‡ p. 11.

nearly resemble those in the Makum field. The prospect of success will be greatly increased when better communications have been established with the Brahmaputra, and it is to be hoped that the next attempt in this direction will have a more fortunate result.

The following list includes all the localities, that I am aware of, in which oil has been observed* :—

(1.) Petroleum was found by Lieutenant Wilcox in the bed of the Buri Dihing at Súpkong, near the outcrop of a seam of coal (p. 3).

(2.) Several springs were discovered by Major White in the Námrup river below the outcrop of seams of coal (p. 5).

(3.) At Námchik Pathár, near the mouth of the Námchik river, Captain Hannay observed petroleum close to where a seam of coal crosses the bed of the stream (p. 9).

(4.) Petroleum rises, in at least two spots, on the bank of the Námdáng (Makum field), a little below its exit from the hills.

(5.) Springs also occur at the debouchure of the Makum nadi from the hills. When Mr. Medlicott visited these, the discharge of gas was so copious and continuous, that when lighted it flamed almost without intermission, but the discharge of petroleum was inconsiderable (p. 11). Subsequently, when bore-holes were put down, the large quantities of oil previously mentioned were obtained (p. 12).

(6.) At a place called Bápu or Bábu Bor Pung, which is, I believe, in the northern part of the Tipám range, there is a superficial deposit of earthy bitumen, evidently resulting from the saturation of the soil with petroleum and inspissation of the oil. Specimens sent to me by Mr. Greig contain from 35 to 80 per cent. of earthy matter. The mass is said to be a few yards in diameter and about a foot thick.

* The localities where oil has been observed during the progress of the survey are marked in the accompanying maps.

(7.) On the Revenue Survey map several 'pungs' are marked along the western side of the Tipám range near Chapatoli. Some of these are probably petroleum springs.

(8.) Close to the Hukanjuri path, about two miles from Jaipur, petroleum exudes from the bank of a nalla, 50 yards below the 9-feet seam (p. 50). Captain Hannay mentions other springs also in this neighbourhood. The locality called Nahor Pung, where borings were made unsuccessfully in 1866 (p. 11), is about a quarter of a mile distant. Half a mile or more to the eastward there is a spot where petroleum exudes from Sub-Himalayan sandstone.

(9.) There are at least two springs in a nalla half a mile north of the Disang.

(10.) Captain Jenkins mentions several small springs about a quarter of a mile from the Disang (p. 7).

(11.) On the bank of the Teok, near the faulted junction between the Sub-Himalayan sandstones and the Disang group, there is a spot where the former are impregnated with petroleum. The coal measures are in all probability below the surface here.

(12.) Mr. Bruce mentions oil-springs in the bank of the Saffrai, and in another locality not far from his coal quarry (p. 4).

(13.) Some 3 or 4 miles to the south of Tirugáon, petroleum exudes in small quantity from the Sub-Himalayan sandstones.

(14.) At the head of the Tiru I observed petroleum oozing from the coal-rocks in four or five places. Where it is most plentiful, it issues from a rather massive sandstone dipping west 40° north at 80°. There is another spring in the same band of rock, about 100 yards distant.

(15.) At Tel Pung, on the Dikhu, a band of fine-grained, massively-bedded sandstone, similar to that in the Tiru, strikes across the river, dipping west-15°-south at 80°. These beds are inverted, being overlaid stratigraphically by thin-bedded sandstone, dipping east-10°-south at

80°, followed by brown pyritous and carbonaceous shales with sandstone, dipping at 60°. Many of the cracks in the massive sandstone are filled with semi-inspissated petroleum, which also impregnates the rock itself in places. From some cracks it is seen to ooze in minute quantities, and, at certain spots in the river adjacent, globules of petroleum rise at frequent intervals to the surface, as well as streams of marsh gas bubbles. Petroleum and gas issue from the bed of the river close to the abovementioned shales also, the total thickness of rock from which they are given off being over 100 yards.

(16.) Petroleum slowly exudes from between the cracks in the coal of the 2′ 11″ seam in the Hil Ján (p. 70).

(17.) Two or three hundred yards lower down-stream than the 1′ 4″ seam in the Disai valley (p. 77), petroleum rises from the bed of the nalla in small quantity.

Iron.

The principal iron ores found in the area under description are clay-ironstone from the coal measures, and an impure limonite from the Sub-Himalayan strata. The former generally occurs in oblate nodules varying in size from that of a walnut to the bulk of a man's head, but lumps considerably larger than this also exist. When freshly broken, the nodules have a light-grey color, which changes after a time to a brown tint from the peroxidation of the iron. They are generally covered by a shell of hydrous oxide, from the character of which some idea can be gleaned as to the purity of the specimen. The ore is also found in thin bands, interstratified with the shales and sandstones.

The following percentages of iron have been found in samples from different localities:—

		Percentage of iron.
Nodular clay-ironstone from near Tirugáon ...	..	40·1
„ „ „ „ „ Tel Pung ...	...	32·2
„ „ „ „ „ „ ...	...	22·1
Layer of clay-ironstone, west of Tel Pung ...	...	23·6

Not unfrequently, masses of a superficial ferruginous conglomerate or breccia are found, where hydrous ferric oxide, deposited by water

which has percolated through the ferriferous beds of the coal-measures, has cemented gravel or angular fragments into a compact rock. Sometimes the oxide is tolerably free from foreign matter, and is sufficiently rich for use as an ore.

The ferruginous beds of the Tipám group have been already mentioned (p. 28). In mineral character and geological position they resemble the deposits of Lohárgarh in the Dárjíling district,* and of Káládhúngí and Déh-Chaurí in Kumáon,† but they are poorer as ores than the latter. Samples of the more highly ferruginous portions from Dholbagán and Náphuk yielded respectively 35·2 and 32·6 per cent. of iron, but the average amount is considerably less.

In former times both descriptions of ore, but more especially the clay-ironstones, were worked extensively by the Assamese, and the remains of their pits and the slag from their furnaces are still to be seen. Tirugáon and Hattighar appear to have been two of the most important places of manufacture, and thirty or forty workshops are said to have been established there at one time. But even before the incursion of the Burmese, the industry had greatly decreased on account of the disturbed state of the country; and, according to Colonel Hannay‡, the ironworkers and smiths, who numbered 3,000 during the most flourishing period in Upper Assam, did not exceed 100 after the invasion. When Mr. Bruce visited the Saffrai valley in 1828, clay-ironstone, which was got by sinking pits to a depth of 10 to 40 feet, was being smelted at the hill east of Tirugáon. The raw iron was worked up into *dhaus* which were exchanged with the Nágás for the produce of their hills. According to Mr. Robinson§, the manufacture of iron in Upper Assam was all but extinct in 1841, the causes that led to its abandonment being the injudicious taxes levied on the ore by the Rájá, and the under-selling of the home-made iron

* Vol. XI, p. 65.

† Records, Geological Survey of India, Vol. VII, p. 18.

‡ Journal, Asiatic Soc., Bengal, Vol. XXV, p. 330.

§ A Descriptive Account of Assam, p. 34.

by that from the Khási hills, where no duties were exacted, and still more by that from England. Colonel Hannay states that in 1856 there were "only from forty to forty-five persons in the Seebsagar district who understand the smelting and working of iron ores." Most of these, however, were probably smiths, not smelters. At the present time the manufacture is entirely abandoned. There are blacksmiths who work with English iron and steel, but there does not appear to be a single smelting furnace from Makum to Golághát.

As to the quantity of ore, there is a large amount scattered through the measures, and enough is to be procured with little difficulty to keep any number of native furnaces going. But whether the supply obtainable in any one locality would be sufficient to feed an English blast-furnace is more doubtful. I have not myself seen what could be called an abundant supply anywhere. In some places the nodules occur in considerable numbers, but not in profusion, and the bands are thin, as well as, I think, of poorer quality than the lumps.

The ore in the Sub-Himalayan beds is inexhaustible, but the quality is very poor, and the scarcity of limestone in the Nágá hills must always be a difficulty in the way of smelting operations on a large scale.

Alum Shales.

The readiness with which some of the pyritous shales from the coal-measures exfoliate is very favorable to the rapid oxidation of the pyrites. Such shales could be used for the production of green vitriol and alum, and if any considerable quantity were incidentally raised in the course of mining for coal, it might be found possible to conduct the manufacture on profitable terms.

Limestone.

Limestone is very scarce amongst the rocks occurring in the area surveyed.

Large nodules of impure, rather brittle, grey limestone are not unfrequently met with in the coal measures, and loose pieces are brought down by many of the streams. A specimen from the neighbourhood of Tel Pung yielded on analysis—

Calcic Carbonate	38·04
Magnesic Carbonate	21·75
Ferrous Carbonate (with some Fe^2O^3)	9·05
Insoluble (mostly clay)	32·00
	100·84

the rock being an argillaceous dolomitic limestone. Another specimen from the Disai valley gave 53·88 per cent. of insoluble matter.

Another variety of limestone, which sometimes occurs in layers of a few inches or a foot thick amongst the shales, is of a greyish color and extremely tough. A sample from the 38-feet shales near Tel Pung (p. 22) gave—

Calcic Carbonate	41·80
Magnesic Carbonate	27·48
Ferrous Carbonate (with some Fe^2O^3)	9·51
Insoluble (sand and clay)	22·00
	100·79

The coal itself sometimes includes lenticular nodules of limestone, which have a brown color on account of the carbonaceous matter they contain, but they are often intersected by thin seams of colorless calcspar. They seldom exceed a foot in thickness and a yard or two in diameter. A sample from the 6′ 4″ seam of coal in the Tiru nadi (p. 64) yielded on analysis—

Calcic Carbonate	76·20
Magnesic Carbonate	15·94
Ferrous Carbonate	1·00
Carbonaceous matter	6·00
Insoluble incombustible residue	·80
	99·94

Some samples of the first variety of stone (the grey limestone), like that of which the analysis is given, would very likely be found to yield a

useful cement, but others are little more than a highly calcareous sandstone, and it would require some discrimination to distinguish the better kind by the eye alone. The limestone from the coal-seams is easily burnt on account of the carbonaceous matter it contains, and the resulting lime is white and slakes rapidly. But the supply of either kind is very trifling. Enough could, perhaps, be collected to supply a limited local demand, but anything beyond this cannot be hoped for.